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The fifth and final volume of a series concerned with higher educational facilities planning expands the discussion of the utilities planning process initiated in the overview of volume one. Three major classes of utilities--energy utilities, service utilities, and communications utilities are studied. Their influences on the overall physical planning of the campus is stressed, and proper location of central plant facilities is emphasized as being extremely critical. Differences in cost factors related to the accessibility of the campus to existing urban utilities are discussed, as well as the relationship between consideration for future expansion and present budgetary limitations. The planning of the campus utilities must be coordinated within the total physical plan so as to preclude interference with other campus facilities and be compatible with other campus structures in their design and appearance. A bibliography pertaining to utilities is included. (NI)

VOLUME FIVE

GUIDELINES FOR PLANNING [illegible]ITIES

PHYSICAL PLANT PLANNING· UTILITIES STUDIES

GUIDELINES FOR PLANNING IN COLLEGES AND UNIVERSITIES

VOLUME FIVE • PHYSICAL PLANT PLANNING • UTILITIES STUDIES

Report Developed For

THE COORDINATING BOARD • TEXAS COLLEGE AND UNIVERSITY SYSTEM

By
Dr. Charles Pinnell • Project Director

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and

Bovay Engineers, Inc. • Houston, Texas
Project Consultants on Utilities

Texas A&M University • May 1968

COORDINATING BOARD

TEXAS COLLEGE AND UNIVERSITY SYSTEM

SAM HOUSTON STATE OFFICE BUILDING

AUSTIN, TEXAS 78701

In creating the Coordinating Board, Texas College and University System, the 59th Texas Legislature directed the Board to "require and assist the public senior colleges and universities, medical and dental units, and other agencies of higher education in developing long-range plans for campus development."

An early step by the Coordinating Board in carrying out this legal mandate was to conduct a statewide survey of the status of institutional master planning in Texas. In January, 1967, the Board published a report indicating that many colleges and universities in the State did not have master plans which could be considered comprehensive in scope.

As a result, the Coordinating Board entered into a contract with Texas A&M University to prepare a model system for planning in colleges and universities. The volumes which make up the "Guidelines for Planning in Colleges and Universities" are the product of this contracted project.

Student enrollment in Texas colleges and universities will increase rapidly and dramatically during the next decade, and the importance of sound planning cannot be too strongly emphasized.

The process of planning described in these volumes focuses on the creation of a system to permit institutions to identify that which is innovative and unique about their educational program and objectives and to plan in depth within the context of their institutional objectives. Master planning is conceived in these volumes as encompassing the total decision-making framework of the institution. Under such a condition, an institutional master plan becomes a complex document in which the design and location of buildings is but one of the components.

The distribution of these "Guidelines for Planning in Colleges and Universities" by the Coordinating Board is not intended to standardize all planning procedures in Texas higher education or to force colleges and universities into a lockstep approach, physically or otherwise. Rather, the purpose of the volumes is to provide to both public and private institutions illustrations and suggested approaches. We ask that the volumes be accepted in this context.

The Coordinating Board staff expresses deep appreciation to Dr. Charles Pinnell, Michael H. Wacholder, and other members of the research staff at Texas A&M University for the work they applied directly to this study and the direction they gave to the consultants providing assistance to them.

J. K. Williams
Commissioner

ACKNOWLEDGEMENTS

This volume on Utilities Planning is one of five volumes on "Guidelines For Planning in Colleges and Universities" that has been developed for the Coordinating Board • Texas College and University System. The major responsibility for the development of the utilities volume was assigned to Bovay Engineers, Inc. of Houston, Texas, during the early stages of the project.

Sincere appreciation is expressed to Bovay Engineers, Inc. for their assistance on this phase of the planning project. Mr. Richard Robertson and Mr. Eric Lowenthal of Bovay Engineers, Inc. worked diligently with members of the project staff to coordinate this work with other phases of the overall project and this effort is gratefully acknowledged.

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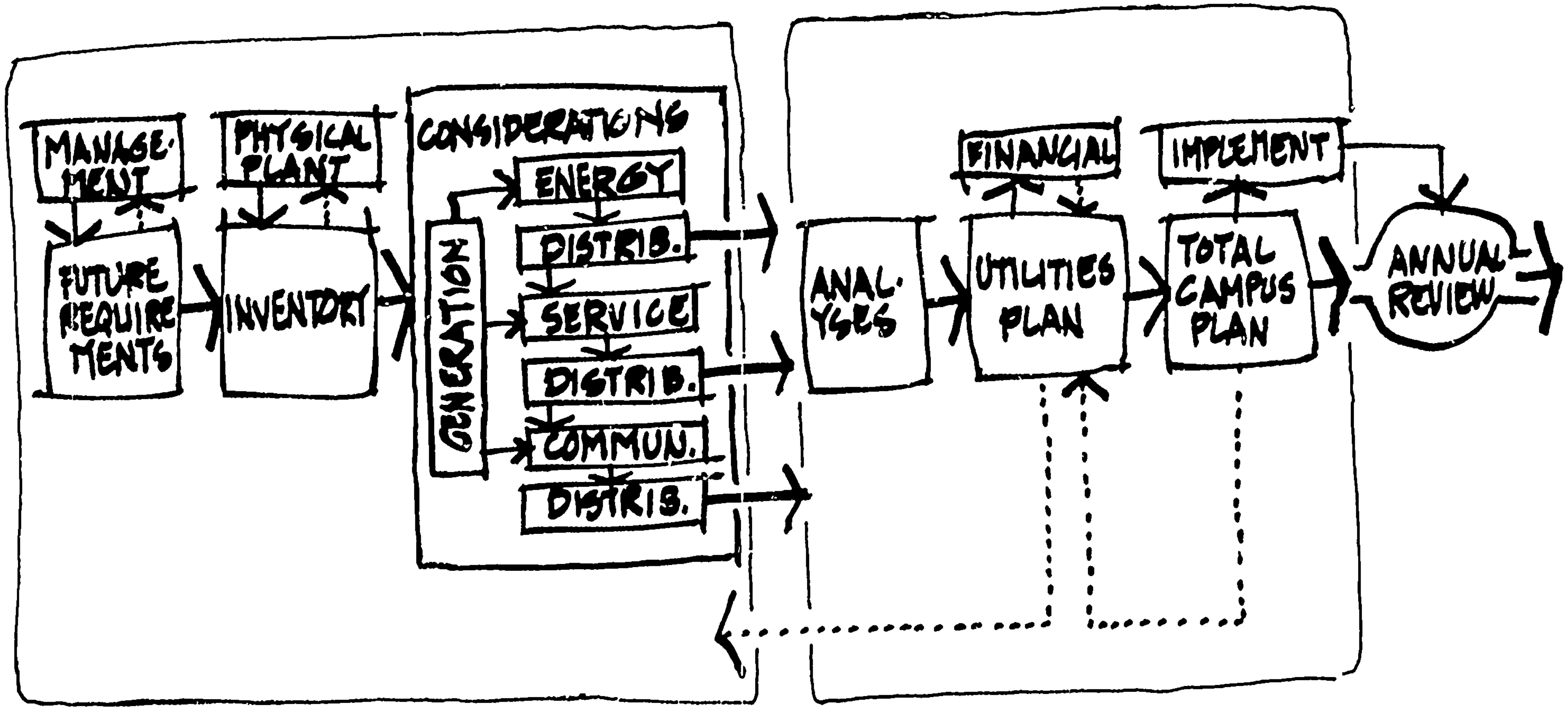


The first volume of this project entitled "Planning System" presented in the concept and format of a total planning system which included a component for utilities planning. Volume I presented an overview of the process for planning campus utilities that was intended for broad usage by physical plant administrators, planners, engineers, and architects concerned with the analysis and decision-making process involved. The purpose of the material that will be presented in this volume is to expand the discussion of the utilities planning process.

GENERAL

Utilities planning must be coordinated with the data developed on the curriculum, the relative proportion and type of research and education facilities, present or initial enrollment in each department or division of the university and projected future enrollment. All of these data from the management planning phase which develops the overall picture as to the type of campus to be served will help establish the utilities requirements of the campus. Planning the utilities systems for the campus without accurate data on the foregoing would be guesswork and would result in revised planning at a later date or possible actual design and construction of systems which would not adequately meet present and future requirements.

The utilities systems should be planned to meet the following criteria:

(1) Adequate capacity for the initial campus construction or expansion;

(2) Lowest capital investment consistent with low operation and maintenance costs and reliable performance;

(3) Provision for ready expansion or change to meet future campus requirements;

(4) Minimum interference with other campus facilities and operation;

(5) Design and appearance compatible with other campus structures.

The development of the utility systems is also influenced by the physical arrangements of the campus facilities. The difference between a compact campus and a widely spread campus will not only require different utility systems layouts, but in many cases, completely different concepts. Conversely, since the utility systems represent approximately 15 percent (%) of the initial construction cost of the campus facilities and 28% of the annual operating costs, the planning of utility systems should influence the physical arrangement of other campus facilities.

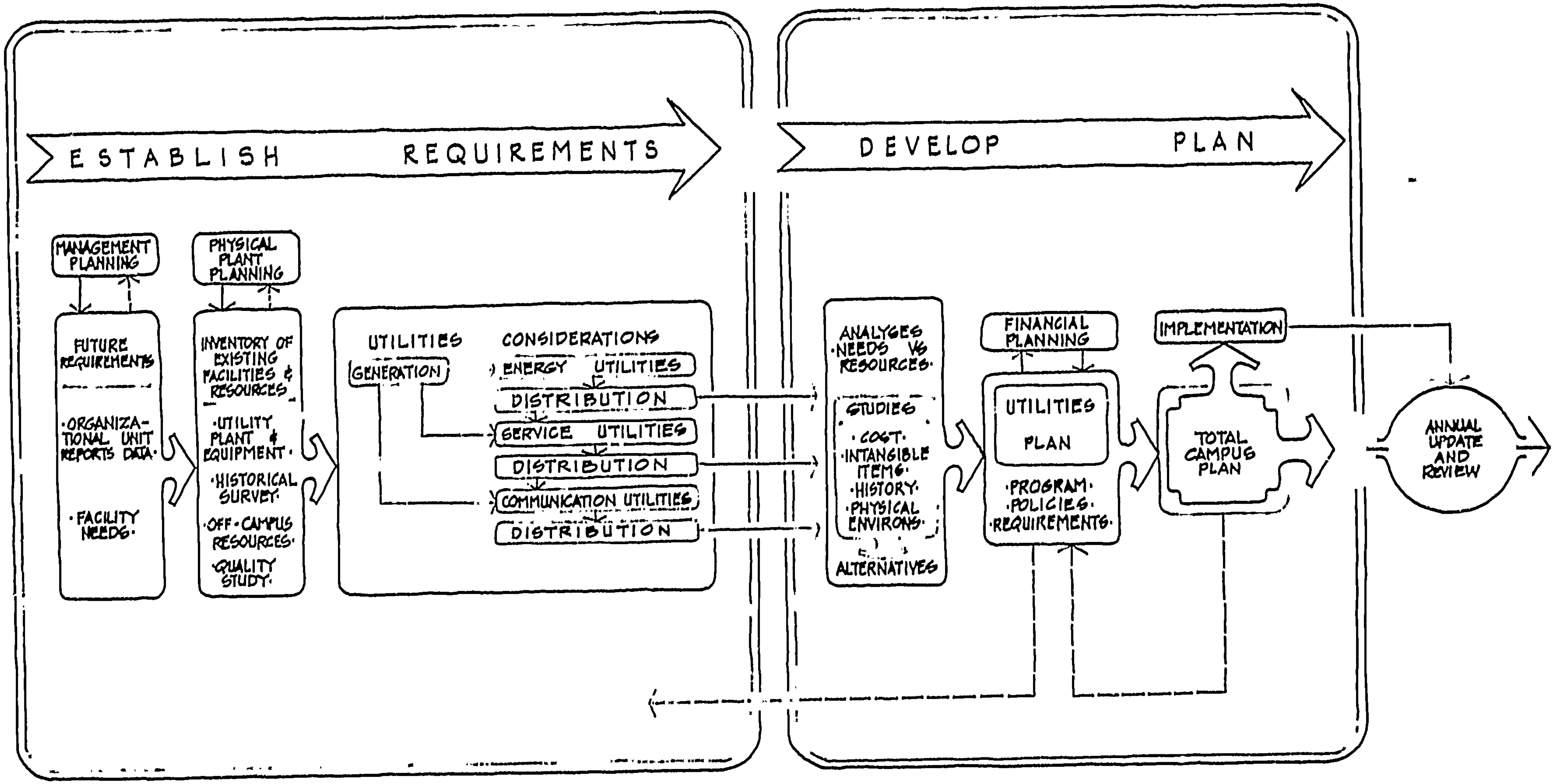
There is a need for continual reference and coordination of utilities planning with other aspects of the planning process during the preparation of any master plan for development of a campus. Strategic location of central plant facilities and proper planning of initial and subsequent campus building locations can result in low cost utility systems initially, and continued low cost with expansion through good planning. Poor initial planning may produce expansion bottlenecks and exorbitant utilities costs due to the necessity of revising existing systems instead of orderly expansion in compliance with a master plan.

PLANNING PROCESS

Before providing specific discussion of individual utilities, it is desirable to establish a framework of reference for the total utilities planning process and to specify a systematic work flow. Figure 1 is a graphical presentation of a planning process that will be utilized for this purpose. This figure illustrates the major components of the process, the logical flow, and the inputs that are required from other phases of the total university planning effort.

Figure 1 will be used throughout this volume to emphasize the total process and to provide a visual reference of individual components to the total system.

FIGURE 1 · UTILITIES PLANNING PROCESS



UTILITY SYSTEMS

The utility systems for a campus can be divided into three categories for planning purposes:

(1) Energy Utilities.
(2) Service Utilities.
(3) Communications Utilities.

Energy utilities include services for space conditioning, electric service for power and light and steam for various uses. These utilities are the most costly, both in initial cost and operating cost and, consequently, have the greatest incluence on the physical arrangement of the campus.

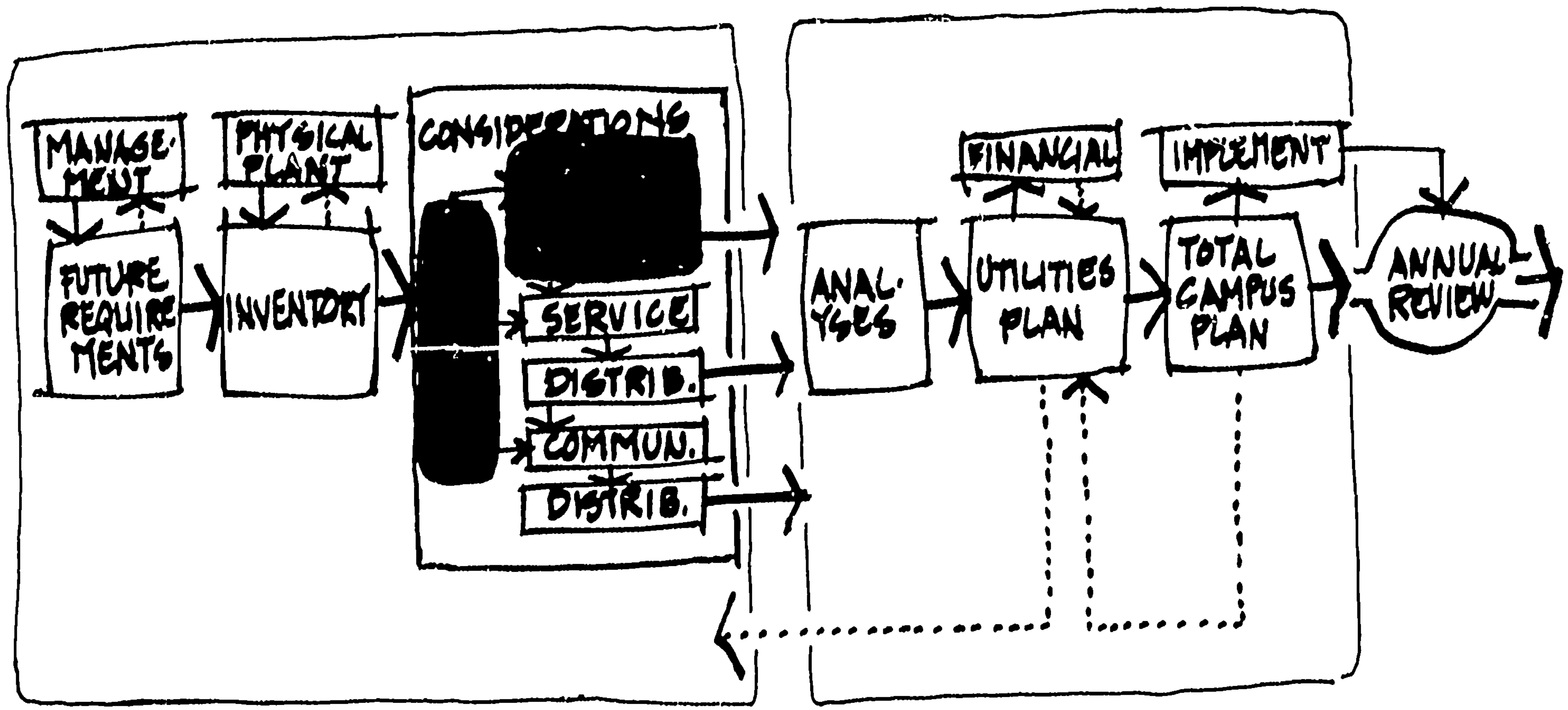
Service utilities include water supply, sewerage, drainage and compressed air. Their costs will vary with the physical arrangement of the campus, but are generally not significant in the determination of the campus layout.

Communications utilities include telephone, telegraph, radio, pneumatic tube, clock and signal and data transmission and retrieval. The cost of these utilities and their details of design is affected more by the type and size of the university than by the physical arrangement of the facilities.

For each of these utilities there are many questions to be asked and answered in their planning, including such things as the utilization of central utilities plants versus individual building systems, the question of on-campus generation of electric power versus purchase from outside sources and the provisions for an effect of growth considerations in expansion of the campus enrollment and activities as they affect campus utilities.

There follows a detailed discussion of these three categories of utility systems and their relationship to overall university planning.

ENERGY UTILITIES



GENERAL

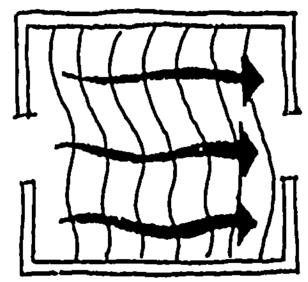
The energy utilities of space conditioning, electric service and steam are a very important element in campus planning because:

1. Their cost is significant and,
2. They are in continuous service for the operation of the university.

Good control of space conditions has grown to be an important factor in building design. Improved lighting layouts and levels of illumination are also required. This has resulted in increased power requirements for the campus to provide this space conditioning and lighting, as well as the increased power consumption in research laboratories.

The energy utilities have the greatest effect on the physical arrangements of a campus, mainly because their installed costs are high and these costs may be concentrated in individual buildings or in a central plant. In the case of the central plant, the distribution costs are also an important part of the total and the desire to decrease the length of the distribution lines for the various energy utilities will usually influence the distance between buildings. Decreasing distribution line lengths also lowers operating costs as line losses due to friction vary with line length. The cost of distribution systems utilizing tunnels may amount up to $400 per lineal foot of tunnel or more.

SPACE CONDITIONING



The most important of these energy utilities in reference to its cost and its effect on the campus planning, is that of space conditioning. The control of temperature, humidity and air flow, or circulation, within the individual buildings is generally accomplished by one of many available types of air distribution and recirculation systems. These can involve one or more primary air fans, a cooling coil and a heating coil. There is also required a control system complete with valves and dampers to regulate the temperature, air flow and humidity, within the individual spaces or zoned area as may be the choice. There may also be secondary air fans, mixing boxes, individual room fan units and various other accommodations of air moving equipment, ducts, dampers, grills and outlets to accomplish the purpose of distributing and recirculating air at the proper temperature and humidity.

It is not the purpose here to describe in detail the types of building air conditioning systems which are in use today, nor to evaluate them, but to assume that all of the buildings on a modern campus will have a system for controlling the space condition, in particular wherein they are inhabited by a faculty and students.

ENERGY FLOW

The immediate consideration then is the question of providing the energy flow required for this space conditioning, which is usually accomplished by supplying either some type of freon or chilled water to the cooling coil in the air distribution system, and supplying hot water or steam to the heating coil. There must also

be a source of power for the turbines or motors driving the air distribution fans either in one central building location or many such units in individual rooms. Again, this is normally an electric motor drive, but depending on the size and type of system, there can be instances of steam turbine driven fans. Also, a variation from the heating coil is sometimes provided by a direct fired duct type heater, wherein natural gas is the fuel and this heat is supplied at various points in the duct distribution system, or possibly one large heater.

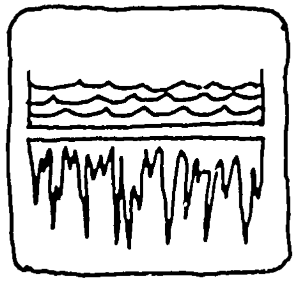
ENERGY SOURCE

A heating coil may be provided with either steam or hot water boilers in a utility plant within individual buildings. Or there may be a piping distribution system of steam or hot water from a central utilities plant on the campus to the individual buildings.

The cooling coils of the individual air handling units may be supplied in a closed system of piping with a refrigerant such as freon or chilled water. Alternately, chilled brine or ammonia can be used as a cooling medium although they are uncommon in present day plants, and are generally reserved for special applications. Chilled water, the most frequent medium for the cooling coil, is supplied from a water chiller either located in the same building or remotely in a central utilities plant located elsewhere on the campus. In the latter case, chilled water is piped to the individual buildings and their air handling coils. Freon is provided from a compressor and then piped from direct expansion cooling coils. The compressor is normally located near the cooling coil because of the loss of efficiency and inherent problems with extended freon piping systems.

There follows a detailed discussion of each of the basic cooling and heating systems such as chilled water, freon, heating water, steam and condenser water, with these discussions presenting the various systems possible under each, equipment selections and variations, and advantages and disadvantages.

CHILLED WATER



The primary utilization of chilled water is for cooling and dehumidifying air in buildings. Secondary uses may include cooling drinking water and certain laboratory uses. This chilled water may be supplied from a central utilities plant or from chillers in the individual buildings. The capacity of the system is a function of the temperature difference between supply and return and the flow. Chilled water is usually supplied and controlled at a temperature of 38° F (degrees Fahrenheit) to 45° F. Return water temperature can vary with load requirements. The differential between the supply and return temperatures in the distribution system is usually established at 8° F to 16° F. Chilled water circuits may have variable flow rates and constant temperature differentials or constant flow rates and variable temperature differentials. System pressure will vary with variable flow. Adequate control devices should be installed to permit control of the range of flow and temperature required or desired. Capacity control of water chilling equipment is necessary to match variable load requirements.

CENTRAL PLANTS

If a central utilities plant is used for the other campus requirements of power and heating water generation, the distribution of chilled water from such a plant would fit in well with these other campus requirements. A more detailed discussion of the advantages and disadvantages follows in later chapters.

The system of water chillers in the central plant may have series flow through the chillers or parallel flow with individual chiller water pumps in parallel. Both flow and pressure gradient will vary with demand loads. Light loads can result in low flow through parallel loops. Such flow and pressure variations may neutralize the action of control valves and steps should be taken to control such conditions. This can be accomplished by varying pump speed, or the number of pumps in operation, or by the use of bypasses between supply and return lines to accommodate light load operation and maintain relatively constant flow.

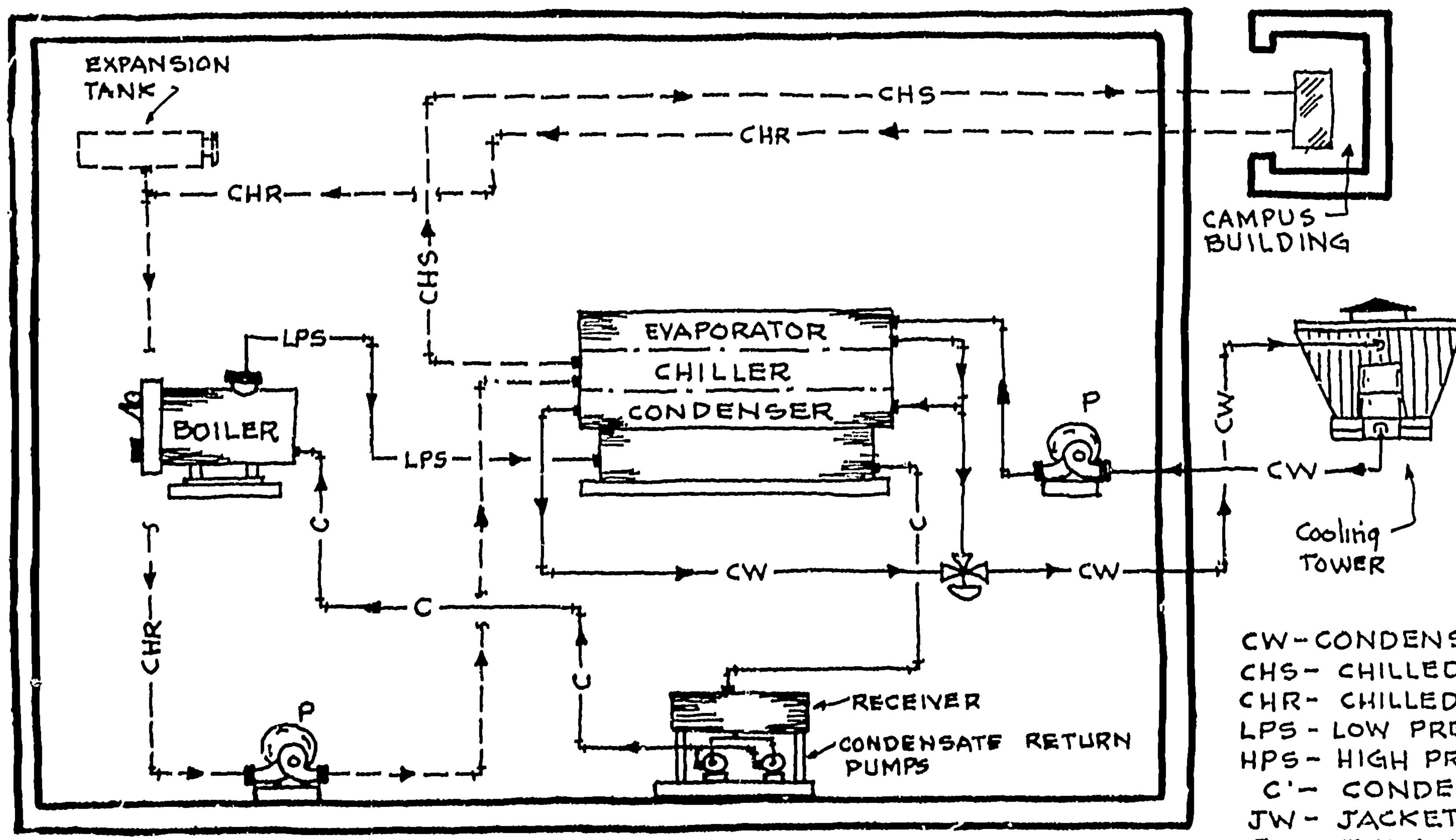
In some municipal areas, it may be possible to purchase chilled water from a utility or adjoining facility. In this case a comparison of costs of owning and operating is desirable to assist in deciding whether to purchase or install chilling capacity. In some cases adjoining institutions may purchase chilled water from the campus plant where this is permissible and to the advantage of the selling institution.

EQUIPMENT SELECTION

The water chilling cycle and its components will be governed by the physical layout of the buildings, and the distribution system required. The size of the plant, either central or in individual buildings, available sizes of machinery and its cost, the utility costs and type of operating personnel are all important factors in selecting a system. The water chilling is usually accomplished by the use of either reciprocating or centrifugal compressors or absorption type machines, and in case of the first two, the compressors may be driven by steam engines, gas engines, steam turbines, gas turbines, or electric motors.

Direct-fired gas equipment is available up to about 25 tons refrigeration capacity. Absorption units are available to approximately 1,000 tons using steam or high temperature hot water as the energy source. Where gas or other fuel costs are low, these systems have a low operating cost. Their first costs, however, may be higher than electric systems, particularly if additional boilers are needed.

FIGURE 2. **STEAM ABSORPTION WATER CHILLING UNIT FLOW DIAGRAM**



CW - CONDENSER WATER
CHS - CHILLED WATER SUPPLY
CHR - CHILLED WATER RETURN
LPS - LOW PRESSURE STEAM
HPS - HIGH PRESSURE STEAM
C - CONDENSATE
JW - JACKET WATER
ES - EXHAUST STEAM
P - PUMP

The most economical gas powered equipment is generally gas engine driven compressors. There have been some installations with gas turbine driven centrifugal compressors. Objections to gas engine equipment would be higher maintenance costs, noise level and space requirements which would generally make them undesirable for individual building chilling plants, although not so objectionable in central plants. Size limitations would be the important consideration in central plants.

FIGURE 3·**ENGINE DRIVEN WATER CHILLING UNIT FLOW DIAGRAM**

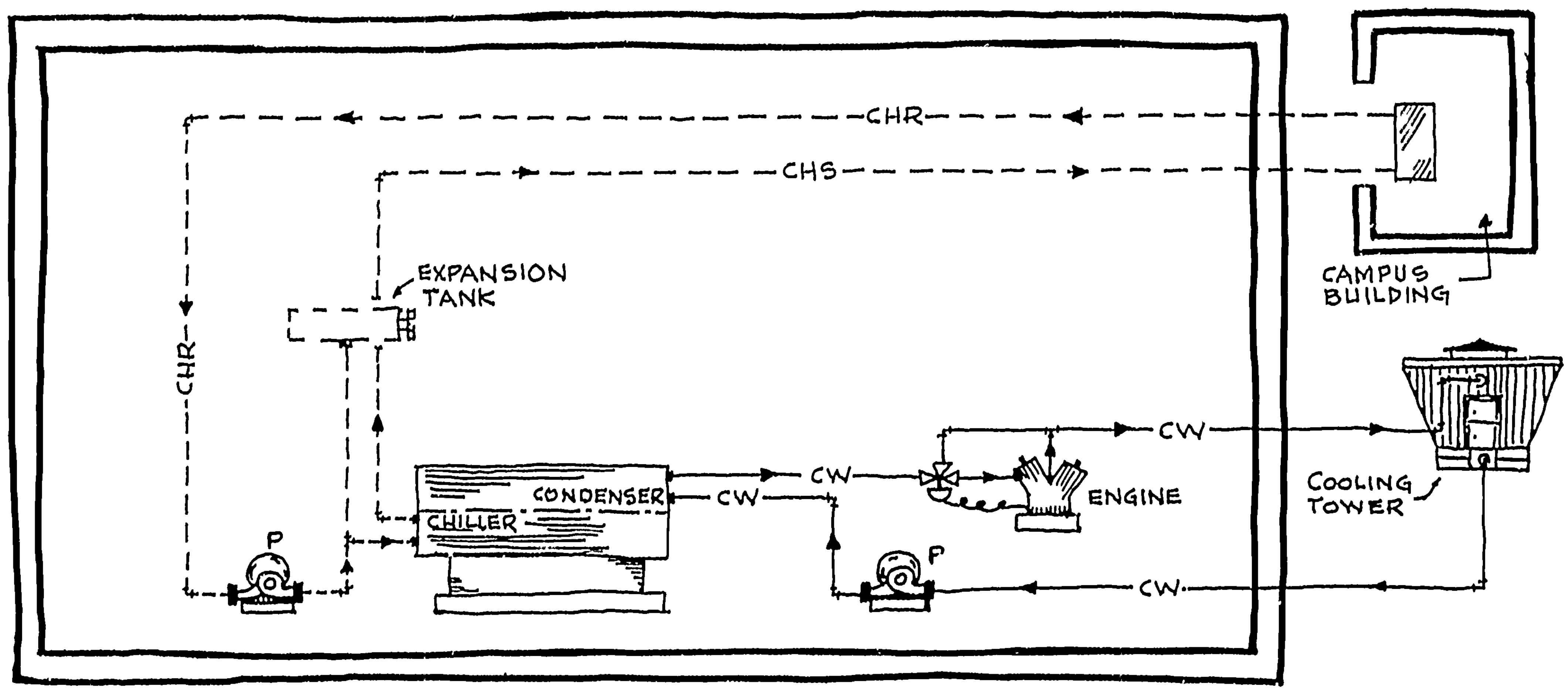
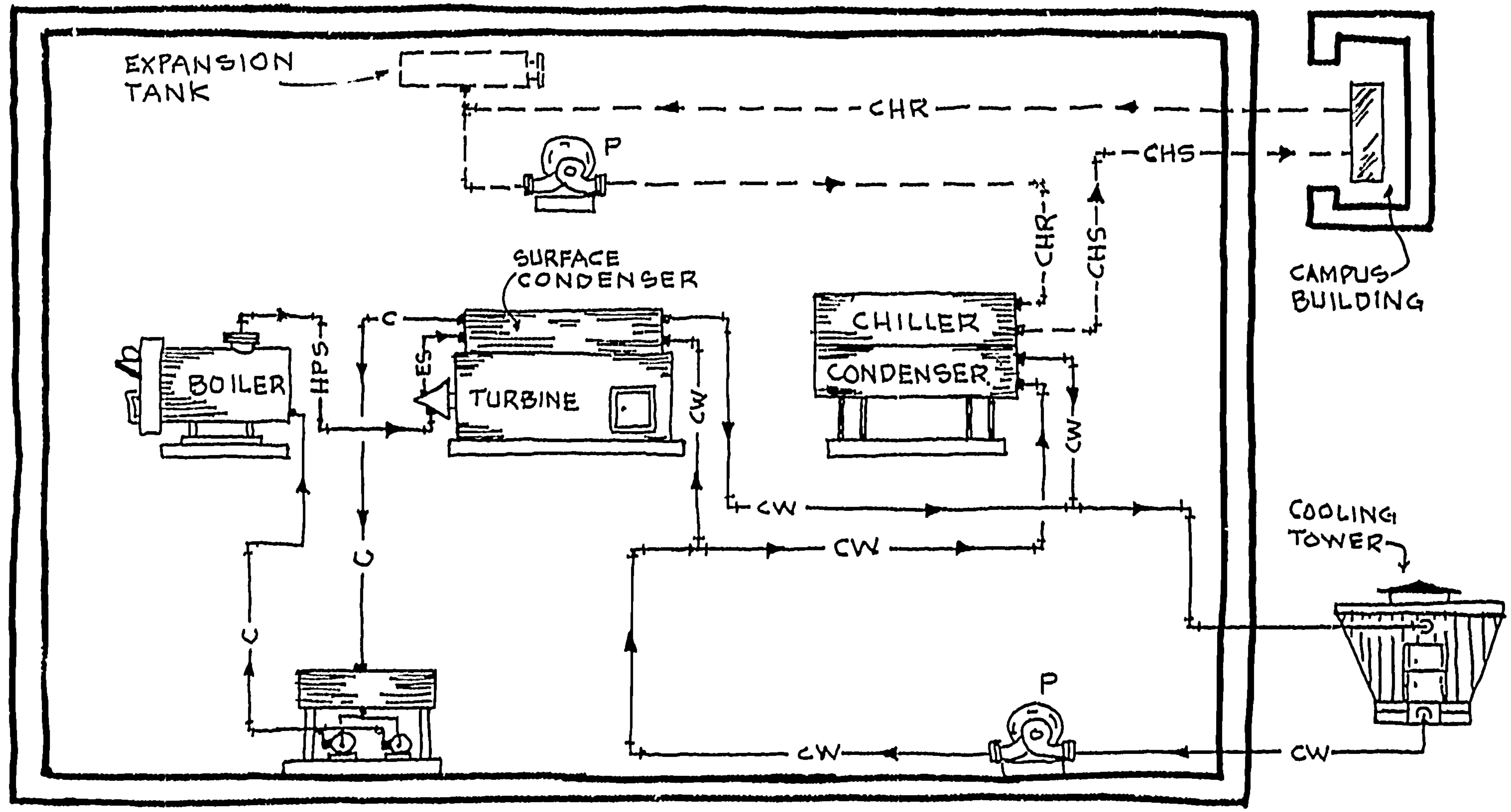


FIGURE 4·STEAM TURBINE DRIVEN WATER CHILLING UNIT FLOW DIAGRAM



Steam turbine driven chillers are used generally in large tonnage installations where high pressure steam is available. Individual steam turbine driven centrifugal compressors are available in sizes up to 5,000 tons or more. These systems have long life, a high degree of reliability and low operating costs. They are generally used in central utilities plants because of their size and the economy to be realized in the larger sizes.

Electric motor driven reciprocating and centrifugal compressors are both used extensively. Hermetic or sealed systems are available up to 2,000 tons. Electric motor driven open compressors are available in single units up to 5,000 tons or more. These systems have wide application and provide low cost cooling when electrical rates are low.

FIGURE 5·ELECTRIC MOTOR DRIVEN WATER CHILLING UNIT FLOW DIAGRAM

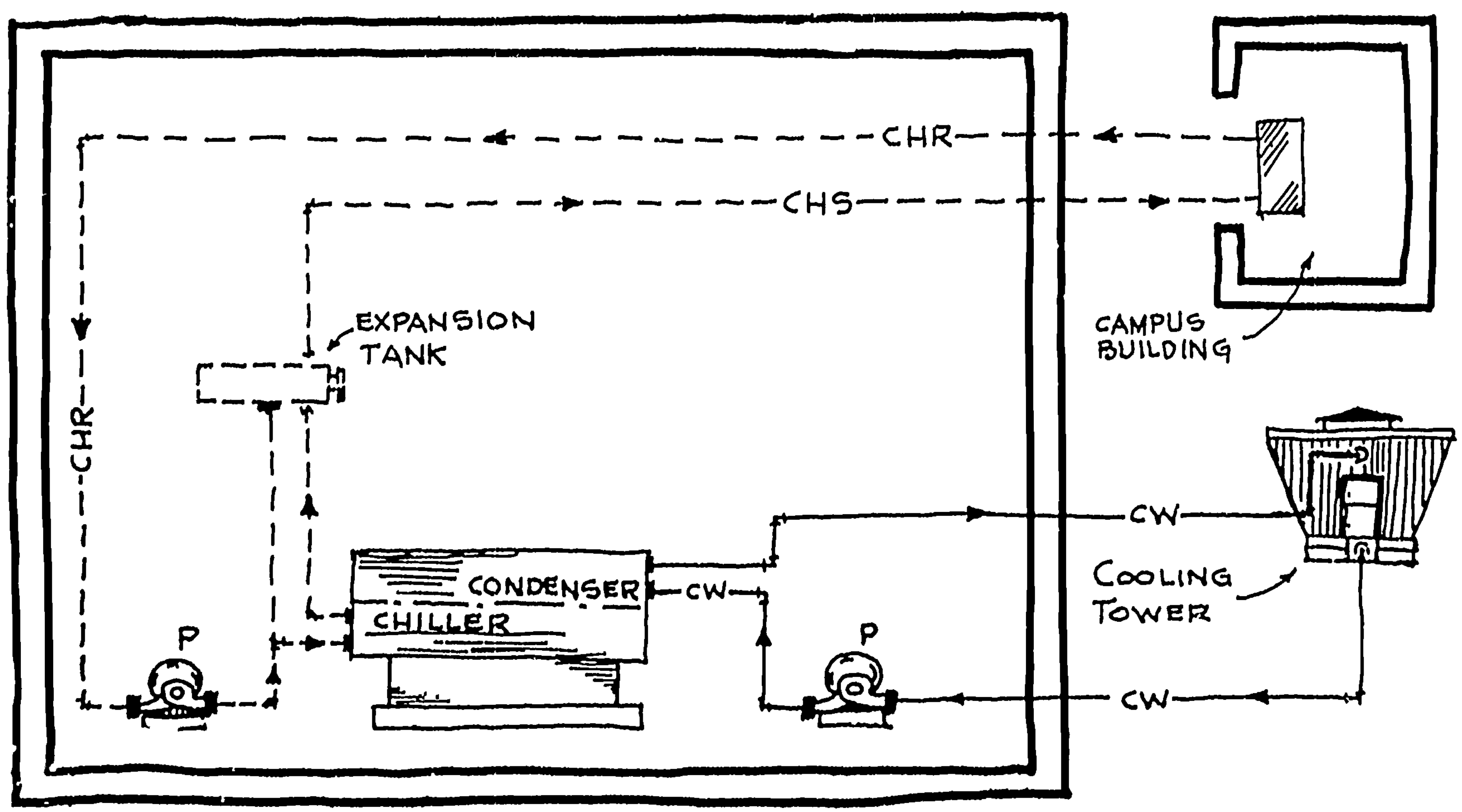
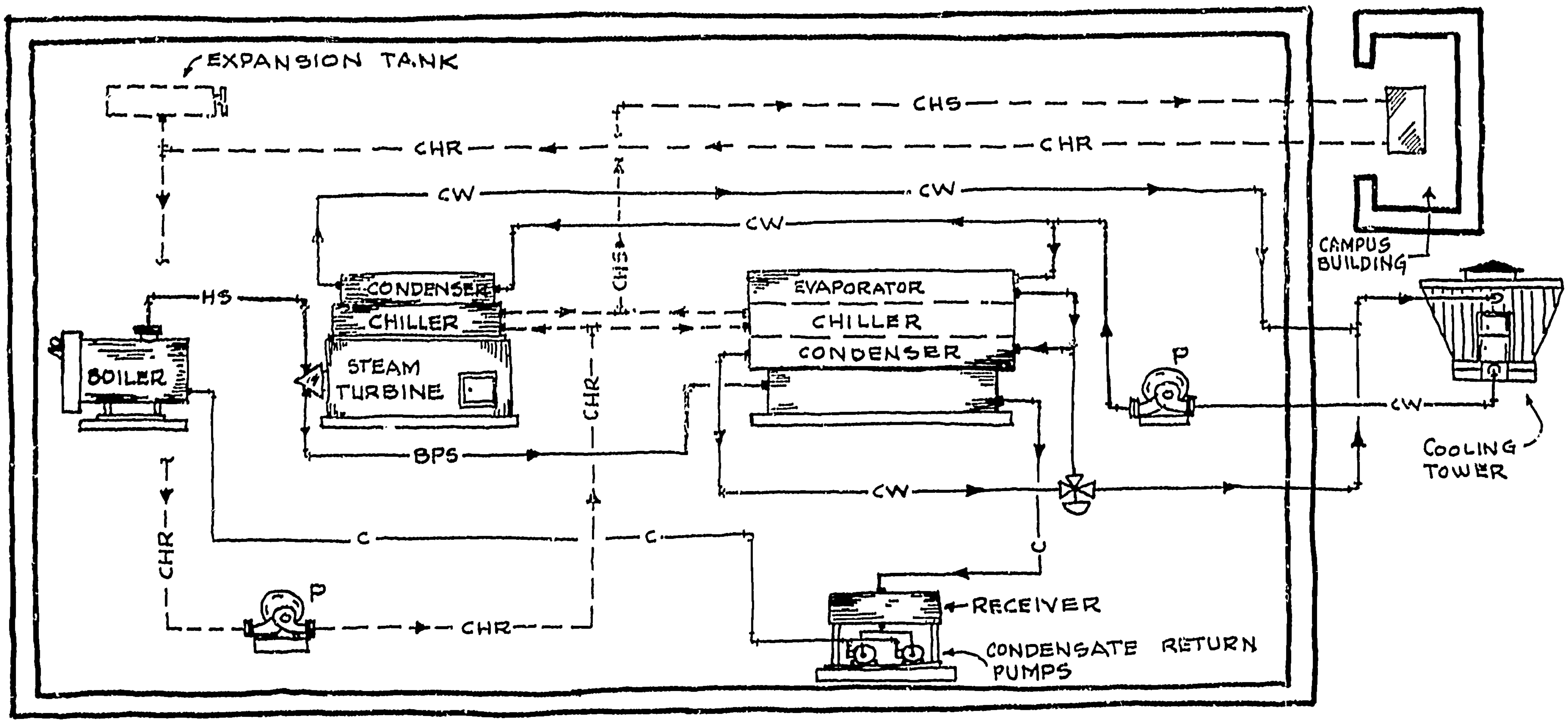


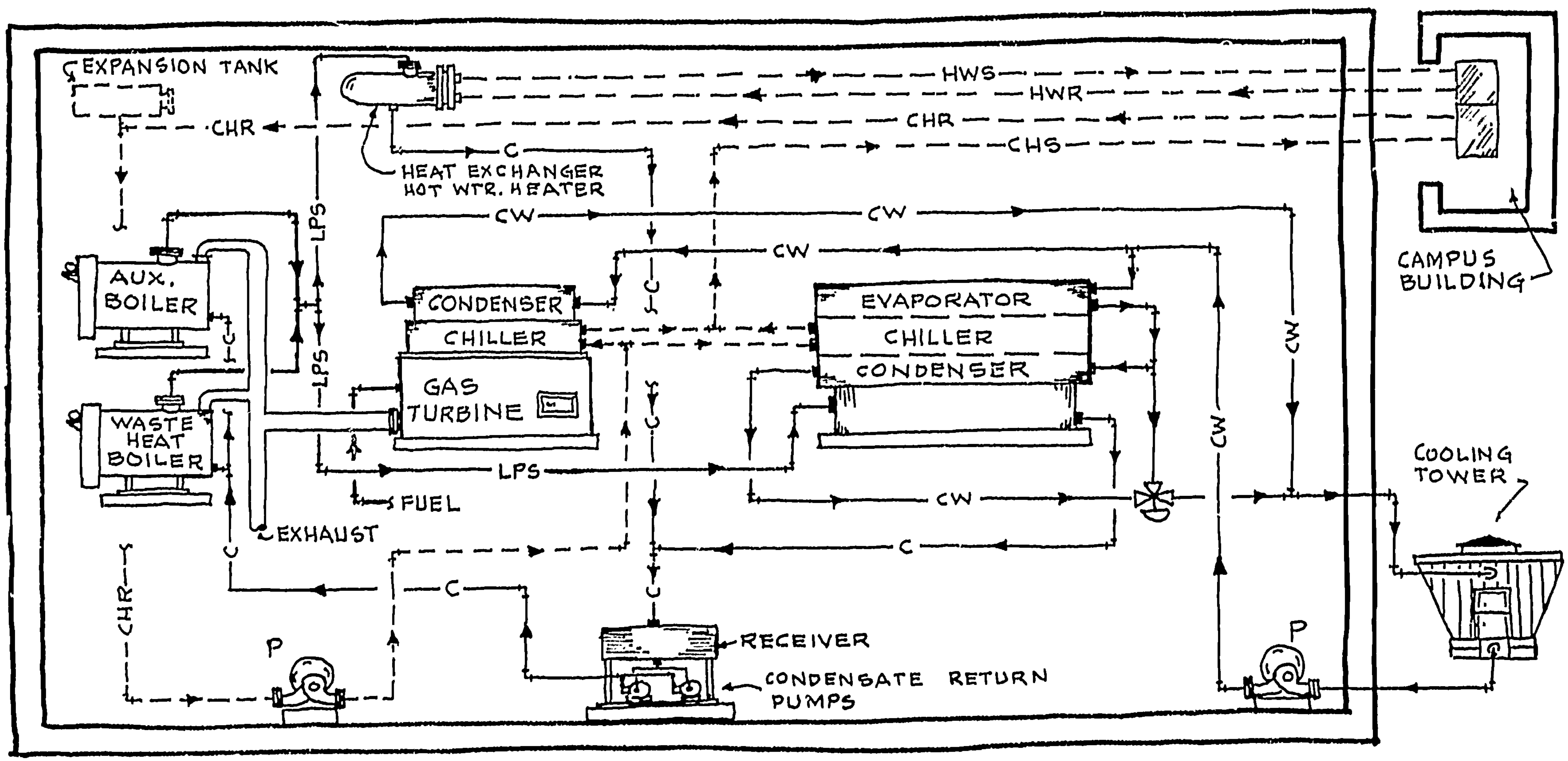
FIGURE 6·COMBINATION STEAM TURBINE DRIVEN WATER CHILLING UNIT AND ABSORPTION CHILLING UNIT FLOW DIAGRAM



One variation from the normal system as described in previous text would be that shown above in Figure 6. A high pressure steam turbine exhausts into an absorption machine utilizing the latent heat of the steam. With fairly constant loads this system can be used to good advantage with high efficiency.

Alternately, a gas turbine can be used to drive the centrifugal chiller and the exhaust heat from the gas turbine used to generate steam for a steam absorption chiller.

FIGURE 7· COMBINATION GAS TURBINE DRIVEN WATER CHILLING UNIT AND STEAM ABSORPTION REFRIGERATION UNIT FLOW DIAGRAM



AUXILIARIES

The auxiliaries required with any water chilling plant, either in individual buildings or from a central system, consist generally of centrifugal pumps to circulate the chilled water. In the case of central plants, there will also be booster pumps at the buildings to provide the exact head needed in each building. Pump selection is an important item and consideration must be given to connecting the chillers in parallel or in series. There must be careful selection to match central utilities plant pumps with building system pumps. Pumps are generally constant speed electric motor driven, although two-speed electric motors and variable speed fluid drives may be used. Steam turbines with reduction gears and variable speed may also be used.

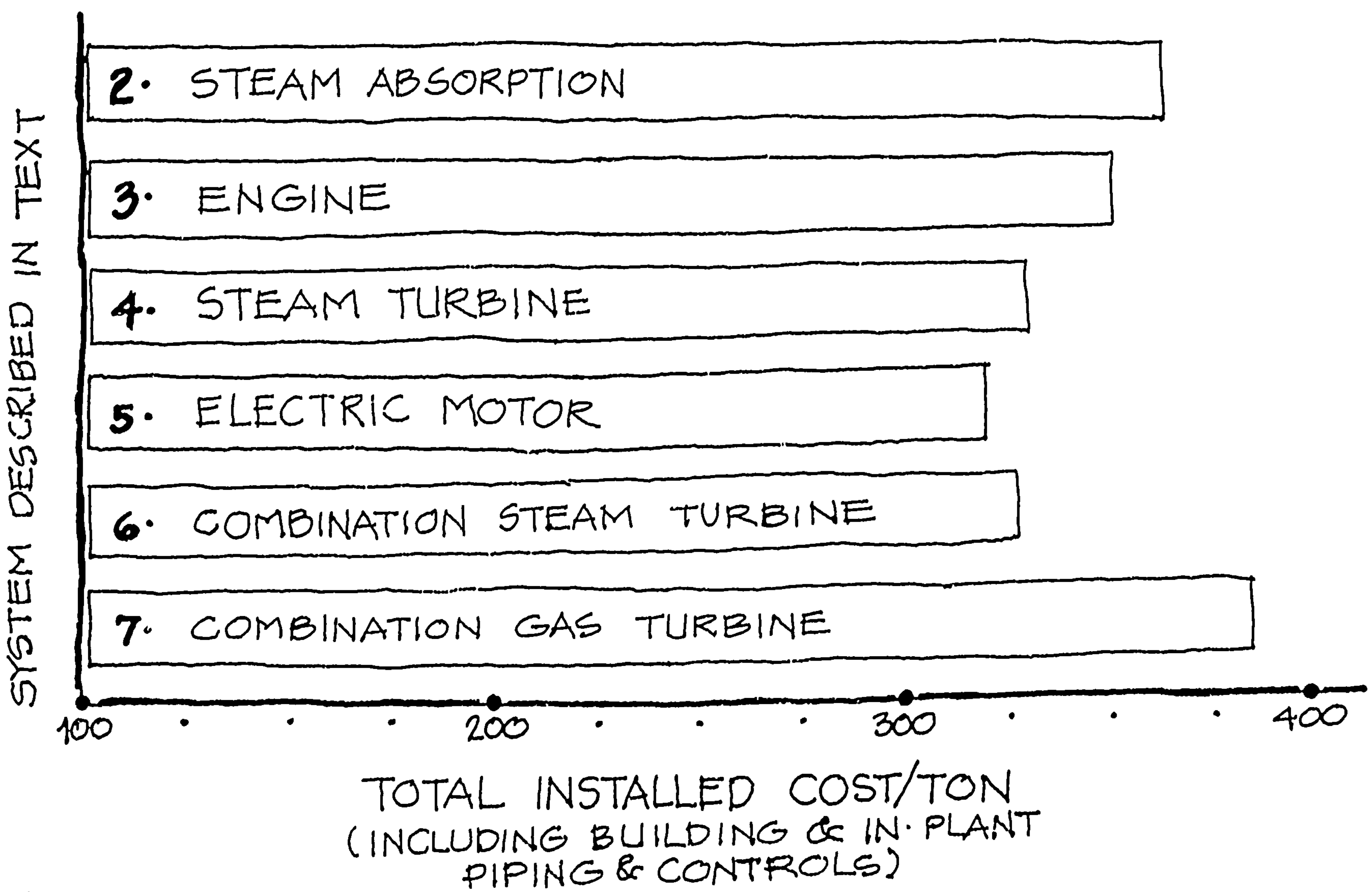
DIRECT EXPANSION SYSTEMS

There will be some instances in campus building space conditioning systems where it will be desirable to use in the individual buildings a reciprocating compressor utilizing freon as a refrigerant and piping the freon directly to the expansion coils in the air handling units. This type of system is usually limited to small tonnage and designs where the air handling units are located in the individual building main equipment room along side of the refrigeration compressor or in separate equipment rooms usually not more than 100 feet from the main equipment room. This type of system is lower in initial costs but it is rather inflexible and may have high maintenance costs including freon replacement costs. This type of system would be recommended only for small buildings where first cost was of extreme importance.

COMPARATIVE COSTS

Generally the initial design incorporating the use of chilled water will, in the long run, be the most economical because of its flexibility, lower operating costs and better control. Following is a chart on average initial cost per ton of refrigeration for various type systems.

FIGURE 8 · **AVERAGE INITIAL COST — WATER CHILLING SYSTEMS**



Consideration should also be given a central utilities plant combining power generation and water chilling and heating, commonly called total energy plant. This system utilizes secondary heat energy from the generation of electric power to produce chilled water and heating water for space conditioning. A total energy system is particularly applicable when the cooling load and heating load profiles are compatible with the electric load profiles and when power generation is economically competitive with local purchased power. A total energy system is generally high in first costs and requires more skilled operating personnel, but the feasibility is usually good as the operating costs will be low, due to the high thermal efficiency of the plant.

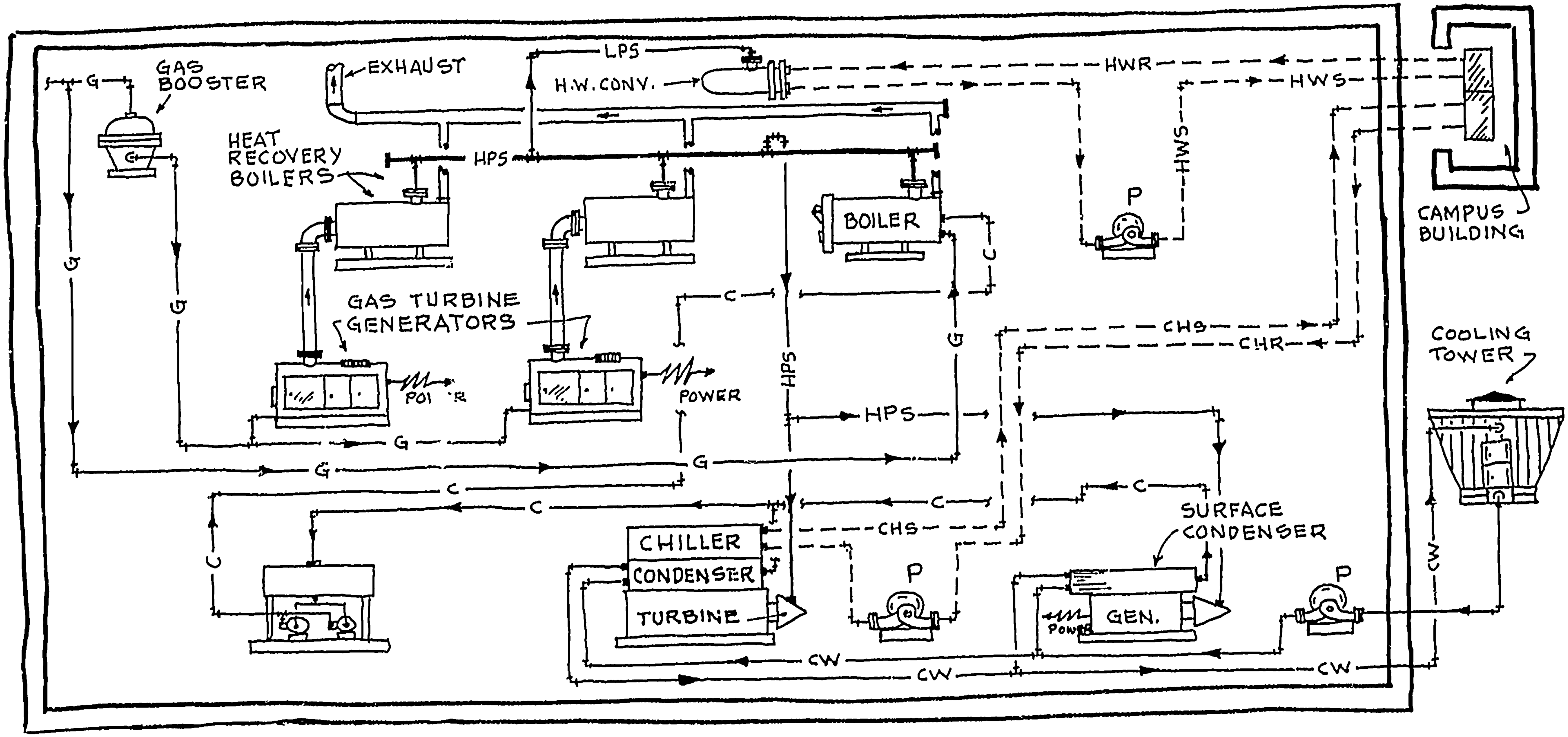
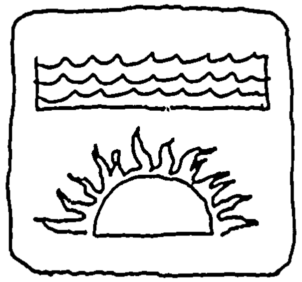


FIGURE 9 · TOTAL ENERGY SYSTEM FLOW DIAGRAM

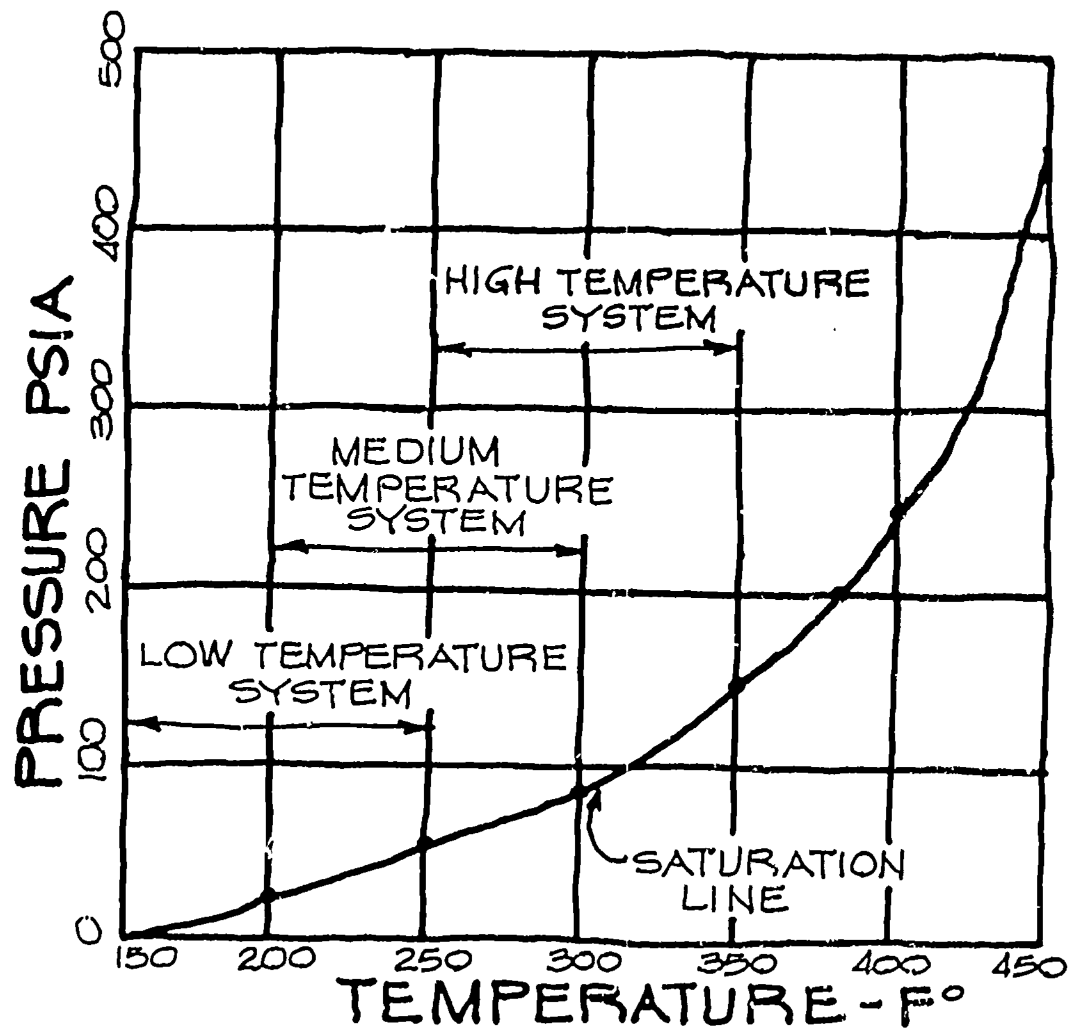
Such an energy system generally uses exhaust heat energy from either exhaust or extraction steam from a steam turbine generator, or the heat in the exhaust of gas turbines, and in some cases the exhaust from internal combustion engines. Also, the heat from the jacket water of internal combustion engines is commonly used. This secondary energy may be used in the form of steam driving low pressure steam turbines, in turn driving centrifugal compressors, or it may be used in steam absorption type water chillers, and, of course, used to heat water for building heating. A more detailed discussion of total energy systems is covered later.

HEATING WATER



The use of hot water for space heating in campus buildings is common today. This water is usually provided from a water heating system in the individual building, or distributed from a central utilities plant water heating system. It is pumped to the individual heating coils of the air handling units serving the building. The temperature of water as supplied may range from a low temperature of 120°F to 215°F in low temperature systems, up to 350°F in medium temperature-high temperature high pressure systems, or up to 450°F in full high pressure-high temperature heating water systems.

FIGURE 10 · TEMPERATURE RANGES OF HEATING WATER SYSTEMS



The most common system used in individual buildings is the low temperature system and the temperature is reset depending upon outside air temperature with the highest temperature of 215° F being utilized at the time the outside air temperature is lowest. This temperature reset is usually accomplished automatically and is combined with an anticipator in order to always assure sufficient heat content in the water to control the building space conditions as desired.

This water may be heated in a hot water boiler in an equipment room in the individual building, and piped directly to the air handling unit heating coils and returned by a circulating pump to the hot water boiler in a closed system. When the water heating system is located in the individual building, it is almost always a low temperature system.

CENTRAL PLANT

Central utilities plant water heating systems generally utilize steam from steam boilers which may be used also to provide steam for electric power generation and water chilling as well as water heating. This steam is provided to steam-water heat exchangers and the condensate returned to the steam boilers. On the other side of the heat exchanger, water is heated to the desired temperature and circulated by pumps throughout the campus to the individual buildings where it is utilized directly in the air handling coils or through heat exchangers to heat water in a closed system within the individual building. The most common system for central utilities plants is a medium pressure system, but there also may be an economic justification for a high pressure system where the spacing of the buildings is quite wide and the amount of distribution system extensive.

HIGH TEMPERATURE SYSTEMS

The use of high temperature water will reduce piping sizes and pumping costs. The temperature of the high temperature system is maintained without flashing of the steam by pressurizing the system with steam or an inert gas. The system is closed with both supply and return mains under pressure.

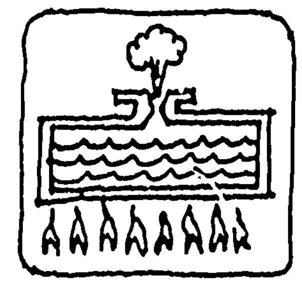
In some high temperature hot water systems the water is heated directly in hot water boilers utilizing forced circulation from pumps with booster pumps then being used for distribution to the campus and in the individual buildings. In this type system heat exchangers are eliminated, but the hot water boilers are of special design.

AUXILIARIES

The auxiliaries required are generally the circulating water pumps. The heating water system distribution and pumping is similar to chilled water pumping as described with the pumps and various drivers available as indicated for chilled water.

STEAM

SPACE HEATING



An alternate source of heat energy for space conditioning is steam at various pressures. This may be provided in the individual buildings by steam boilers, but this is infrequent in campus design due to the complications of a steam boiler system requiring condensate return. Water treatment and controls are much more elaborate than with the simple hot water boiler. Steam can also be supplied from a central utilities plant, but again the economics do not favor it as the piping becomes much larger for the supply line, although the condensate return lines are smaller. Also, the maintenance on steam piping, valves and controls is generally higher than on a hot water system and the insulating cost is higher.

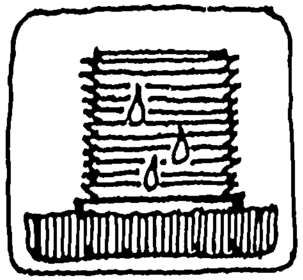
Steam can be used directly in the heating coils of air handling units, but it has a disadvantage of poor regulation of temperature. The controls are more simple on a water coil than on a steam coil. Also, at partial loads there is a greater tendency to have stratification with steam coils.

SPECIAL USES

Steam as an energy utility is more often used for special applications rather than space conditioning. These uses are generally for campus cafeterias, kitchens, laundries, and special laboratory requirements. The pressure and temperature required will depend on the individual campus requirements

but the usual campus will not require steam at a pressure higher than 100 psig (pounds per square inch gauge) for these uses. Usually most of the condensate is lost from these special uses although there may be some condensate return to the central utilities plant. This increases make-up of boiler water and may require more boiler water pretreatment depending upon the quality of the raw water supply to the campus.

CONDENSERS



Condenser cooling will be required in connection with space conditioning to reject the heat from the refrigerate medium. For individual building systems this is generally provided by water from a cooling tower located adjacent to the building or on the roof of the building. Air cooled condensers may also be used for small systems.

CENTRAL PLANT

One of the advantages of a central utilities plant as discussed in a later chapter is the removal of condenser water equipment such as cooling towers from the immediate area of campus buildings, and providing cooling towers at the central utilities plant. When chilled water is provided from a central utilities plant, the condenser water system will be from cooling towers or possibly from

ponds, lakes, reservoirs, bays, or streams in the immediate area. This water will be used to cool refrigeration equipment condensers and also may be used for other equipment in the central utilities plant such as steam turbine condensers, jackets of internal combustion engines and miscellaneous cooling and for bearings and seals on rotating equipment such as pumps.

COOLING TOWERS

Cooling towers are usually induced draft with fans located at the top of the tower although there are several variations from this arrangement. These may be single cell or multiple cell towers. Each cell usually has its own fan and its own circulating water pump. The fan may have a two-speed electric drive or steam turbine.

Towers are provided in multiple cells usually in order to permit cleaning of individual cells without stopping operation completely and also to permit shutting down individual cells as the cooling load on the tower decreases in daily and seasonal cycles.

Towers may be constructed of steel, redwood, ceramic or other materials.

PUMPS

Circulating water pumps for towers are generally low head, large volume centrifugal electric motor driven pumps. They are frequently vertically mounted, taking suction from the tower basin and pumping the cool water through the various condensers in the central utilities plant and back to the top of the tower. Water

flow is generally varied by the number of pumps in operation in order to maintain a fairly constant temperature differential between the supply and return lines and maintain high efficiency utilization of the individual tower cell.

WATER TREATMENT

It will usually be necessary to provide treatment of the condenser water to reduce scaling in the heat exchange units and to control biological growth and cooling tower cell packing deterioration in the cooling towers. This treatment will vary with the quality of the water supply and should be carried out under the guidance of water treating specialists.

COOLING PONDS

A cooling pond may be used for condenser water cooling. It may be desirable when land is inexpensive, rainfall seasonal, humidity moderate and wind relatively high. The cooling effect is obtained through spray nozzles using a spray head pressure of 5-15 psig. Large areas are required.

Spray ponds will require more algae treatment than cooling towers in order to prevent spray-head stoppage. Control of the water temperature is provided by controlling the piping arrangement and number of spray heads used at any one time to control the temperature differential between supply and return water.

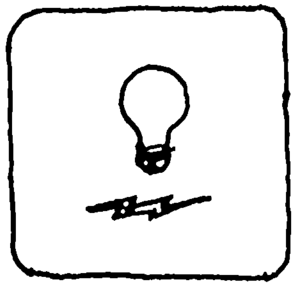
RIVERS, LAKES AND PONDS

Where a river with large flow is available, a condenser water system may be simply a matter of pumping out of the river through the condensers and back into the river downstream of the intake point with very little treatment required and only a protective screen at the pump inlets being necessary. Depending on the turbidity of the water, frequent flushing of condensers may be required including backwashing, but in some cases the river water may be of sufficient clarity as to require no treatment or special handling. The amount of circulating water required and the sizes of the condensers must be coordinated with the historic river water temperatures on a seasonal basis in order to assure adequate cooling capacity. Some rivers are controlled by regulatory bodies and permits may be required.

Where lakes or reservoirs are used, the inlet must be remotely located from the outlet and the area must be large enough to effect the required cooling by evaporation.

The type and size of condenser water system is usually decided on the basis of initial and operating costs. Other factors include limitations on the utilization of ground area and such aesthetic limitations as may be imposed.

ELECTRIC LIGHTING AND POWER



Electric lighting and power is just as important a part of energy utilities as space conditioning. In some ways this is actually part of space conditioning, but there are other uses for electric power in addition to providing lighting for the buildings and in some cases heating. Electricity is commonly used as a source of energy for space heating directly with strips or radiant heaters or indirectly for reverse cycle refrigeration and generation of hot water and steam particularly in areas where the cost of electricity is very low, compared to the cost of other sources of energy, such as natural gas or coal.

Electricity may be used for driving refrigeration and air handling equipment and for such miscellaneous equipment as computers, communications systems, office equipment and audio visual aids.

LIGHTING SERVICE

Of prime importance to campus planning, however, is the use of electricity for lighting the buildings and providing the power for the many services above. The use for which electricity is required determines the demand made upon the power source as well as the load imposed upon the distribution system. In the individual buildings the common voltages used for lighting and

miscellaneous uses are 110 volts or 220 volts. For large motors power may be supplied at 440 volts. In certain systems utilization is made of 277/400 volts distribution for lighting and large motors. Consideration is sometimes given to utilization of high frequency lighting at 600/800 volts.

CONNECTED LOAD AND DEMAND

The first consideration in electric utility planning is to determine the connected electrical load of each building and of the campus as a whole. From this connected load the maximum instantaneous demand is determined by applying a diversity factor, sometimes to individual buildings, or perhaps to the entire connected load. This factor is determined from experience records of similar projects, and it is also contained in certain national codes which specify minimum loads and diversity factor requirements. The National Electric Code 1967 Edition requires that a load not less than the unit load specified in the following table be included for general lighting loads for each square foot of floor area for a specified type of occupancy:

Type of Occupancy	Watts Per Square Foot
Auditoriums	1
Chapels	1
Clubs, Fraternities & Sorority Houses	2
Clinics	2
Dormitories	2
Parking Garages	1/2
Apartment Houses	2

Type of Occupancy	Watts Per Square Foot
Cafeterias	2
Administration	5
Classrooms and Laboratories	3
Book Stores	3
Storage Areas	1/4

Outlets supplying specific appliances or loads should be computed at the actual rating of the loads; heavy duty lamp holders at 600 watts per lamp holder, and other general outlets at 180 watts per outlet. Motor loads are computed at actual horsepower rating of the motors.

The National Electric Code also recommends the following demand factors for lighting loads:

Occupancy	Portions of Lighting Load to Which Demand Factor Applies (Wattage)	Demand Factor
Dormitories	First 3,000 or less at	100%
	Next 3,001 to 120,000 at	35%
	Remainder over 120,000 at	25%
Clinics	First 50,000 or less at	40%
	Remainder over 50,000 at	20%
Apartments with-out provisions for cooking	First 20,000 or less at	50%
	Next 20,001 to 100,000 at	40%
	Remainder over 100,000 at	30%
Storage	First 12,500 or less at	100%
	Remainder over 12,500 at	50%

Occupancy	Portions of Lighting Load to Which Demand Factor Applies (Wattage)	Demand Factor
Classrooms, Laboratories and all Other	Total Wattage	100%

Motor loads are computed according to usage with a diversity factor of 100% to 50%. Motor loads for air conditioning usually will have a diversity factor of 90%, while shop equipment may run as low as 50%

POWER CONSUMPTION

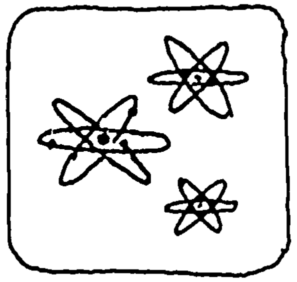
Once the power demand is known, the monthly power consumption can be estimated by multiplying the average anticipated kilowatt demand by the number of operating hours in the month. The power consumption will vary monthly and with the seasons. Therefore, in order to project the annual power consumption, it is necessary to tabulate the monthly consumptions for twelve months. Heating requirements in the winter months, as well as cooling requirements in the summer, greatly affect the power demand and consumption and must be weighed carefully.

POWER COST

With the power consumption known for each month, the annual power cost is determined by multiplying the consumption of each month by the average generating cost per kilowatt hour if the power is generated on the campus. If power is purchased from a utility company, then the monthly cost is determined by use

of the utility company's rate schedule which usually includes factors for maximum kilowatt demand, peak KVA demand, power factor correction and fuel costs depending upon the company's method of determining their costs. The power consumption and demand should be metered in either case.

POWER SOURCES



Knowing the estimated kilowatt demand and the anticipated power consumption, consideration can be given to the economics of generating the power on the campus as compared to the purchase of power from a local utility company. The amount of anticipated power consumption and the possibility of utilization of secondary energy resulting from power generation for other utility systems are important factors. When the power requirements are small (under 2500 KW), it usually is not economically feasible to generate power. However, where power requirements are large and the need exists for secondary energy in heating and cooling, generating equipment with heat recovery accessories should be considered, and the cost of owning, operating and maintaining such equipment should be considered with the cost of purchasing power from the outside source.

POWER GENERATION ON CAMPUS - ADVANTAGES AND DISADVANTAGES

The chief advantage of generation on campus if economically feasible would be lower power costs and concurrently lower space conditioning costs. The main disadvantages are higher initial investment, the difficulty of coordinating generating plant expansion with campus building expansions and the requirement for training operating and maintenance personnel. Also power and frequency regulation may not be as good as that maintained by the utility company, depending upon the size of the campus plant and the quality of the equipment and the operators. On the other hand, most local utility companies can furnish electric power with good frequency and voltage regulation, but they may not be able to offer the power at an attractive price. Generally, the initial capital cost of electrical service is nominal as the utility company usually installs all the equipment necessary without cost to the purchaser. Power can be supplied at any nominal voltage advantageous to the purchaser and at any location. In case of equipment failure, the utility company generally is better equipped with power and maintenance crews and supplied with spare parts, so as to more quickly replace damaged equipment and should be able to keep power outages to a minimum number of times and durations.

The cost of the power varies with the method in which it is purchased and distribution to individual buildings by the power companies is the most expensive way of buying it because each building is usually metered individually. Generally, power will be purchased from a utility company at one point on the campus in order to get a lower power cost at that point. All transmission and distribution of power from that point on the campus to serve the various buildings and loads will be installed by the college and the cost of this system must be included in the distributed cost of power. There also may be occasions where utility companies will restrict the method of starting large motors as well as frequency of starting, and perhaps

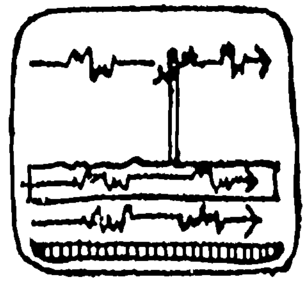
impose other service restrictions, although they are not usually numerous or particularly burdensome. The main disadvantage of purchased power in some areas is its high cost when compared with on campus generation if secondary energy is required by the campus.

In some instances, power generation in the individual building may be required or justified. Alternately, the first building on the campus may include a large central equipment room including power generation, to serve that building and maybe the next several buildings.

This in effect is a modified central utilities plant including power generation and is sometimes a way in which a central plant concept is carried out in starting a campus. It has the disadvantage of requiring an oversized equipment room in the first building and also location of the central plant equipment in the middle of the educational building complex is undesirable. Equipment used for individual building power generation is usually gas engine driven, or gas turbine driven and economic justification is usually difficult to establish. The requirement for reliability of power usually requires 100% standby of the largest unit and this plus the higher unit cost of small generating units will result in a high unit cost of power. The only savings to counter this is the elimination of transmission and distribution systems.

Certain special facilities, such as campus hospitals or medical research laboratories, nuclear research and biological research facilities may require emergency standby equipment to assure continuous uninterrupted electrical service. This requirement may be satisfactorily met by central plant equipment with standby units but more often is provided by a standby engine driven generator sized for the emergency load only and provided with automatic startup when the primary power supply fails.

POWER DISTRIBUTION



Depending on whether the power is purchased at a single point or one or more points or is generated in a central utilities plant, it must be distributed from those points to the campus building. This is accomplished usually by one of the following means:

1. Aerial lines mounted on poles
2. Direct burial of cable
3. Cable run underground in ducts
4. Cable run in utility tunnels installed to serve other utility services.

Power is usually distributed on campus at the purchased voltage or generated voltage and this is commonly 2400, 4160, or 13,200 volts. Distribution may be directly from the purchase source to each individual building by one of the methods listed above, or in some cases to substations serving two or more buildings in a particular area. At the individual building or at the substation the transmission voltage is reduced to the using voltage which in most cases is 440, 220, or 110 volts. A common substation serving more than one building is sometimes used in order to permit the use of outdoor transformers and switch gear and not occupy valuable space in the buildings. On the other hand, it is usually more economical with modern equipment to make this transformation directly from the distribution voltage to the building voltage at the building in a relatively small transformer space. A considerable savings results from shortening the length of the low voltage lines and reducing the amount of expensive cables required at low voltage.

AERIAL LINES

The most economical distribution is by aerial lines mounted on poles. The poles must be sized to clear roads by at least 22 feet and the height of poles is further varied by the distribution voltage.

One disadvantage of aerial lines is their unsightly appearance and the requirement for poles to be installed in front of buildings detracting from what is otherwise an attractive campus. These lines also are exposed to the elements and they suffer damage due to ice or snow or high winds from hurricanes or tornados. There also is a certain amount of hazard involved with exposed aerial lines when heavy equipment is moved in their vicinity.

DIRECT BURIAL

Another economical distribution system is direct burial of cables and this system has become more popular in recent years with development of better cable insulation capable of resisting the normal attack of moisture and soil on the cable insulation. Cables should be covered or cased in red colored concrete for protection to cable and workers who might dig in the area. Disadvantage of direct burial of cables is the possibility of its being cut during construction programs and possible harm to the workers involved. Also it may require moving due to future construction programs and this is more expensive than moving aerial cable.

BURIED DUCTS

A somewhat more costly but safer installation is to run cable in buried ducts. Generally the initial installation is provided with spare ducts so that additional cable can be pulled without

installing new ducts. This type of installation is quite economical and is considerably safer than the above as the concrete ducts prevent accidental damage to the cable. There still may be the need to remove these ducts and cables due to construction and if so, it is expensive to do.

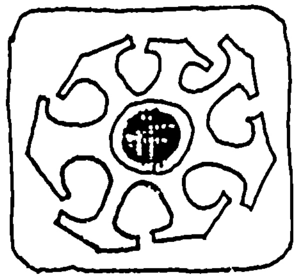
UTILITY TUNNELS

Probably the most satisfactory routing for the distribution lines is that accomplished by installing them in utility tunnels provided for other services. This has the advantage of being flexible as the cables can be easily installed or removed at future dates and it keeps the campus clear of poles and any underground obstructions that might interfere with construction. Obviously the routing of utility tunnels is more carefully planned to avoid future construction and future construction would be planned around the tunnels rather than to require removal of the tunnels. This is economical only if the tunnels are required for other services as the tunnels themselves are quite expensive to build.

The main disadvantage with electrical distribution in tunnels is that the tunnels have to be routed in a most economical way in order to provide the other services which generally are chilled water and heated water. Since their cost of distribution is considerable, the tunnels will favor the routing of these lines. This may or may not coincide with the most economical electric distribution routing and installing the electric distribution lines in the tunnel may involve greater length of line and cost than would be required by direct burial or buried duct installations.

On the other hand, the advantages far offset the disadvantages and if tunnels are available, properly lighted and drained, serious consideration should always be given to the installation of electrical distribution lines in the upper portions of these tunnels.

CENTRAL UTILITIES PLANT



In each of the systems above involving energy utilities, the source of the utility can be the individual building or alternately a central utilities plant serving several buildings as well as the rest of the campus. Historically, these central utilities plants have found their origin as heating plants as even the earliest of campus planners appreciated the operating economies to be realized in a central heating plant versus maintaining individual heating plants in each of the buildings. This was particularly true in the early days when automatic controls were not available and each of these heating plants required constant attention. The central plant has the advantage of having a smaller operating and maintenance crew than would be required with individual plants all over the campus.

Other factors influencing this early choice were the handling of the fuel which was coal or oil and in the case of coal required considerable labor or expensive equipment for handling not only the coal for producing the energy in the boilers, but also the disposal of the resulting ash. All of this was easier to handle in a single central plant than in individual heating systems.

GENERATION OF POWER

Once the die was cast toward the central heating plant, an obvious engineering development in remote campuses not served by electric power from utilities was the generation of electric power in this central plant and in most cases utilizing the same steaming capacity for generation

of power as was used for heating. In more recent years with the advent of complete space conditioning for campus buildings, the further development seemed obvious that this same central plant could be used for chilling of water which would then be circulated to the individual buildings to provide space conditioning. However, at about the same time the air conditioning industry had gone through a manufacturing development producing package type air conditioning units for residential and small commercial application and enlarging these packages and their components as the market grew. As a result, there are available water chilling and freon units for space conditioning in almost any size desired for the individual building and many office buildings and commercial type structures as well as campus buildings were served initially by individual water chilling systems. Only in more recent years have central chilled water plants become the recommended way of serving most campuses.

ADVANTAGES

The advantages to a central utilities plant providing chilled water and heating water for space conditioning and in many cases generation of electric power are as follows:

1. Load diversity reduces the required capacity at the central plant and on many campuses only 65% of the connected load is installed as capacity in the central plant.
2. The installed capacity is usually provided in multiple units and the loss of any one unit does not seriously affect service to all campus buildings. By comparison, the loss of a unit in an individual building will usually mean that the building will be without service until the unit is repaired.
3. Diversity of load, larger sized equipment and more efficient operation, all result in considerably lower operating costs with the central plant than with individual units.
4. Major maintenance is concentrated at the central utilities plant and can be carried out by a smaller crew with a resulting lower maintenance cost.
5. Larger central plant boilers, turbines and chillers can be installed for a lower unit cost than smaller units, and usually have the life expectancy comparable to utility type central plant equipment, at least twice the expected life of units in individual buildings. As a result, depreciation costs are correspondingly lower.

6. With large, units, preventive maintenance and better operators, the reliability of operation is improved and outages are minimal.
7. Concentration of major energy units in the central utilities plant reduces the equipment space requirements in the individual buildings to that required only by the air handling units and permits a greater percentage of the building space to be functional for the purpose of the building. Since this individual building space is more expensive, generally, than the central utilities plant space, considerable savings results there also.
8. The central plant can be planned with space provided for expansion as the overall campus needs require additional central plant facilities and the expansion can be orderly and in major steps. This eliminates the need to dedicate space in individual buildings for future chilling units, for example, and eliminates this need for having space all over the campus dedicated to expansion without actually knowing the amount of space required in each case. As a result, expansion space is more economical and the flexibility is much greater.

DISADVANTAGES

The main disadvantages of a central utilities plant are:

1. The installation of a central utilities plant at the start of a campus construction usually requires a larger initial investment at a time when capital is least available. Any capital funds dedicated to a central utilities plant, which probably is oversized initially in the interest of lower operating cost and efficiency, must be subtracted from funds available to build educational buildings and this frequently is a disadvantage.
2. With the new system and a central utilities plant, the entire distribution system to serve the initial buildings must be installed at one time. Frequently, this distribution system is oversized in order to more easily serve future buildings as they are constructed. This, again, will require a large initial investment at a time when funds need most to be used for educational buildings.
3. Matching federal and state funds are always more difficult to secure for non-academic facilities. As a result, central utilities plants usually have to be funded from a regular

building construction allotment, or in some cases, they can be funded from revenue bonds. This latter type of funding has become more popular in recent years, as it permits construction of a central utilities plant with no burden on the regular building fund, requiring only that sufficient operating funds be assured to retire the revenue bonds required to finance the construction. The interest rate on this type of funding is slightly higher than on tax bonds. This illustrates the need for careful consideration of financing of projects and of construction and operating costs and pressures of inflation or deflation.

CENTRAL UTILITIES PLANT DISTRIBUTION

Distribution systems from central utilities plants for chilled water, heating water and steam would include the utilization of direct burial, conduits, tunnels or lines run on supports just above ground, or overhead under covered walkways. Early designs of central plants occasionally utilized the same piping system for chilled water and heating water, alternating the use with the seasons. This had the disadvantage of permitting the use of only one service or the other during the appropriate season, plus requiring a sizable and expensive changeover of operating temperature when weather conditions would change unseasonably. However, the use of total space conditioning for campuses where air cooling will be required year round for some internal space, while outside rooms may require heating requires separate piping distribution systems for each service.

DIRECT BURIAL

Properly insulated and wrapped chilled water piping can be installed by direct burial in most areas provided the installation is above normal ground water level, and shifting of the ground is not appreciable. This is one of the most inexpensive ways for initial installation of chilled water piping, but has a disadvantage of not being readily available for maintenance or new connections. Heating water can also be installed this way as long as the temperature of the water does not exceed 210° F. Direct burial is not recommended for high temperature water or for steam systems, as any ground water leakage will result in production of steam from the ground water and this steam will emerge above ground. System longevity is usually less than anticipated due to deterioration of the insulation and corrosion of the pipe.

CONDUITS

Another form of installation is the use of conduits, of which there are several manufacturers. These consist of installing a pipe within a pipe and the outside pipe is drained (in some cases by pumping) in order to insure that the insulated pipe is kept dry. This type of installation also has the disadvantage of poor accessibility for maintenance and new connections.

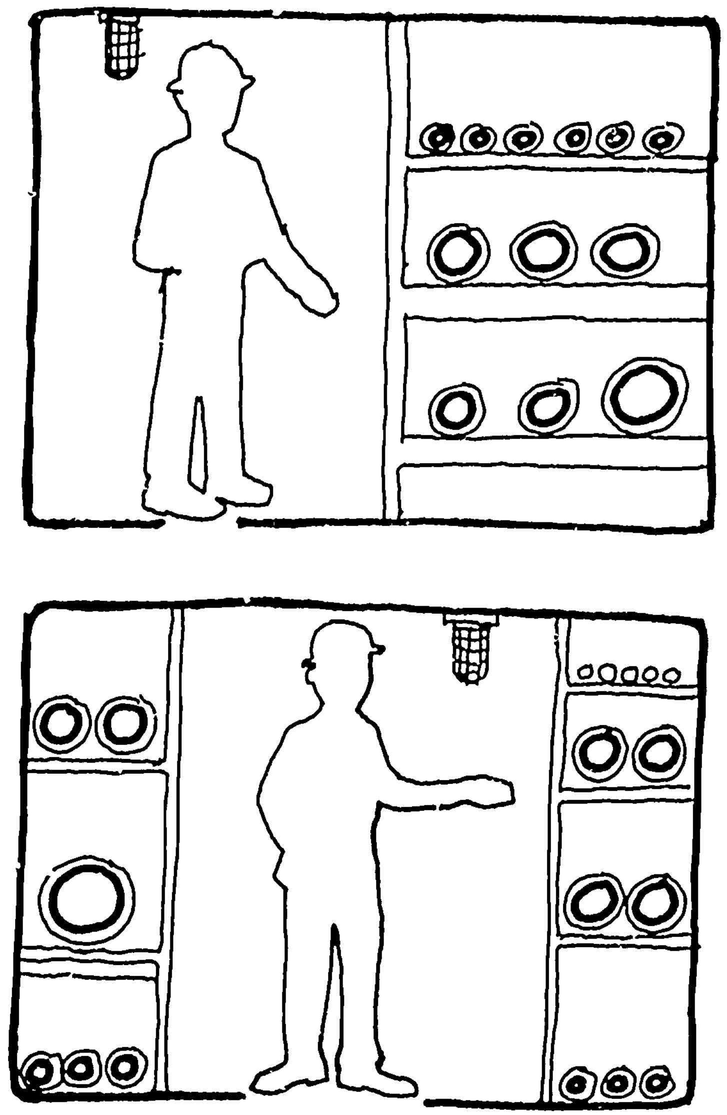
UTILITY TUNNELS

When the various buildings of a campus are interconnected by covered walkways or tunnels, space can usually be provided economically for utilities distribution systems. Accessibility for maintenance and connections can be excellent and this type of installation is usually the most economical over a course of several years. If tunnels are not required for pedestrian traffic

between buildings, they may be constructed for utilities services only. In this case, the tunnels are generally designed to provide space for all utilities services including chilled and heating water piping, electric cables, compressed air piping and communications systems.

Frequently, the chilled water and heating water piping is racked overhead or along one wall, with the electrical cable being at the highest point in the tunnel. Space is provided alongside the piping for a walkway through the length of the tunnel and the tunnels should be of sufficient height as to permit upright walking. Such tunnels must be well drained, lighted and ventilated. Proper planning of their routing will provide a flexible system for future expansion and for maintenance of the utilities distribution lines. Also, maintenance will be considerably less due to the protection of these lines and extended life.

FIGURE 11· UTILITIES TUNNEL CROSS SECTION



INSULATION

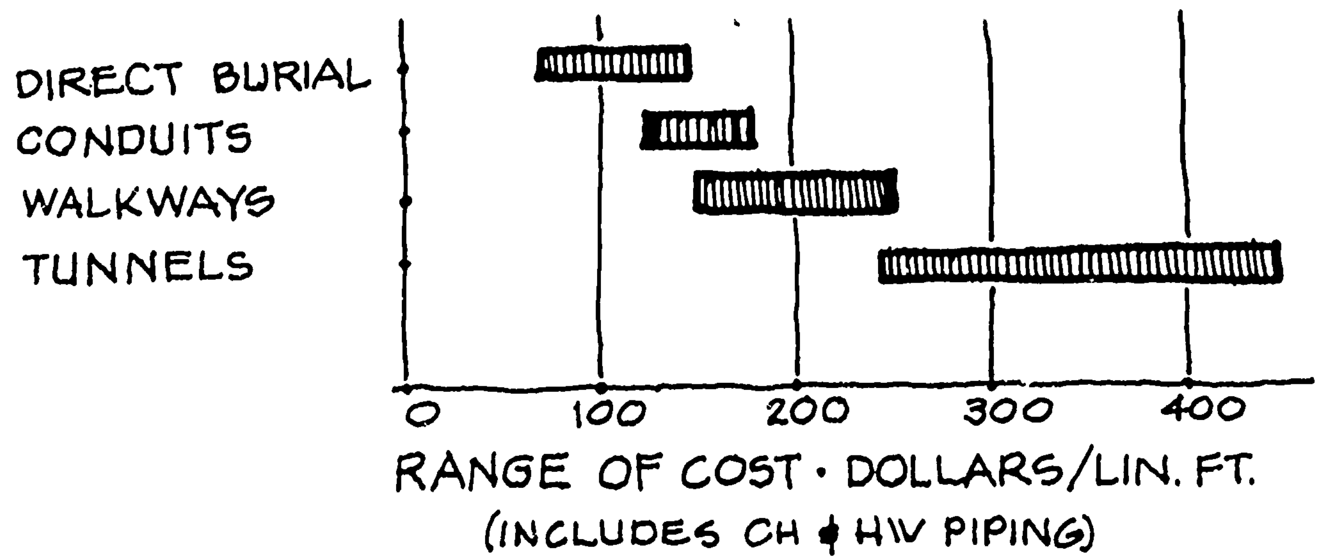
Distribution system piping installed by direct burial method should be properly insulated with a water repellent insulation and should be given protective outer coatings. Also, cathodic protection of the lines may be used in an effort to limit corrosion. This same type of insulation is recommended also for conduits, but the insulation for use in tunnels and covered walkways could be the same as in the central plant with any of several good preformed insulating materials being used with external jacketing of either canvas of aluminum.

EXPANSION

Regardless of the type of installations, expansion loops should be provided as required in all piping having temperature variations. Expansion joints may be used where loops are impractical, but are a source of maintenance problems.

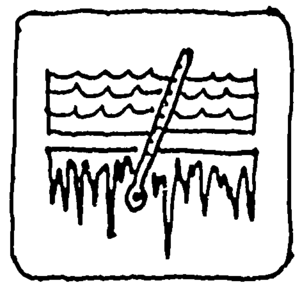
The relative costs of distribution systems utilizing the above methods are shown in Figure 12.

FIGURE 12· **DISTRIBUTION COSTS**



CENTRAL UTILITIES PLANT CONTROLS

TEMPERATURE CONTROL - CHILLED WATER



The primary control required on chilled water is the temperature of the chilled water. Many arrangements are possible to maintain a leaving water temperature from the utilities plant and the temperature differential between the supply and return. Capacity control on the refrigeration units with multiple water chilling units may control leaving temperatures. Multiple pumps may vary circulation rates, thus controlling the temperature differential by varying the flow. Safety controls will be required to prevent freeze-ups and excessive pressures. Also, bypasses may be required to maintain adequate flow rates and these may be installed in the central plant or at the extremeties of the distribution feeders.

MEASUREMENT

When it is desirable to measure the cooling effect delivered to each building, a number of devices are available. BTU meters or ton hour meters measure flow and temperature differential and record on a chart the cooling used.

HEATING SYSTEM

The same type of controls and metering also can be used on heating water distribution systems. Steam is generally measured by the use of orifice type flow recorders and these can be supplied with an integrator to record a cumulative quantity.

Other special controls may involve reset of heating water temperature in accordance with outside air temperature with anticipator where desired.

CONDENSER WATER CONTROLS

Also, condenser water temperatures will generally be controlled and the information utilized to indicate the number of cooling tower cells required to be in operation at any one time. This generally is done by indication and manual change, but it can be made fully automatic. Also, cooling towers are usually provided with two-speed fans to vary the cooling effect and bypasses should be provided in the piping for winter operation, utilizing only the tower basin for cooling. Protection against freezing should be considered in certain areas.

BUILDING CONTROLS

The chilled water from a central utilities plant may be used directly in individual buildings, mixed with recirculated water or used indirectly to cool water in a closed circuit within the building through a heat exchanger. The required piping connections and controls for all three methods are shown in the following Figures.

FIGURE 13. DIRECT USE OF CHILLED WATER FLOW DIAGRAM

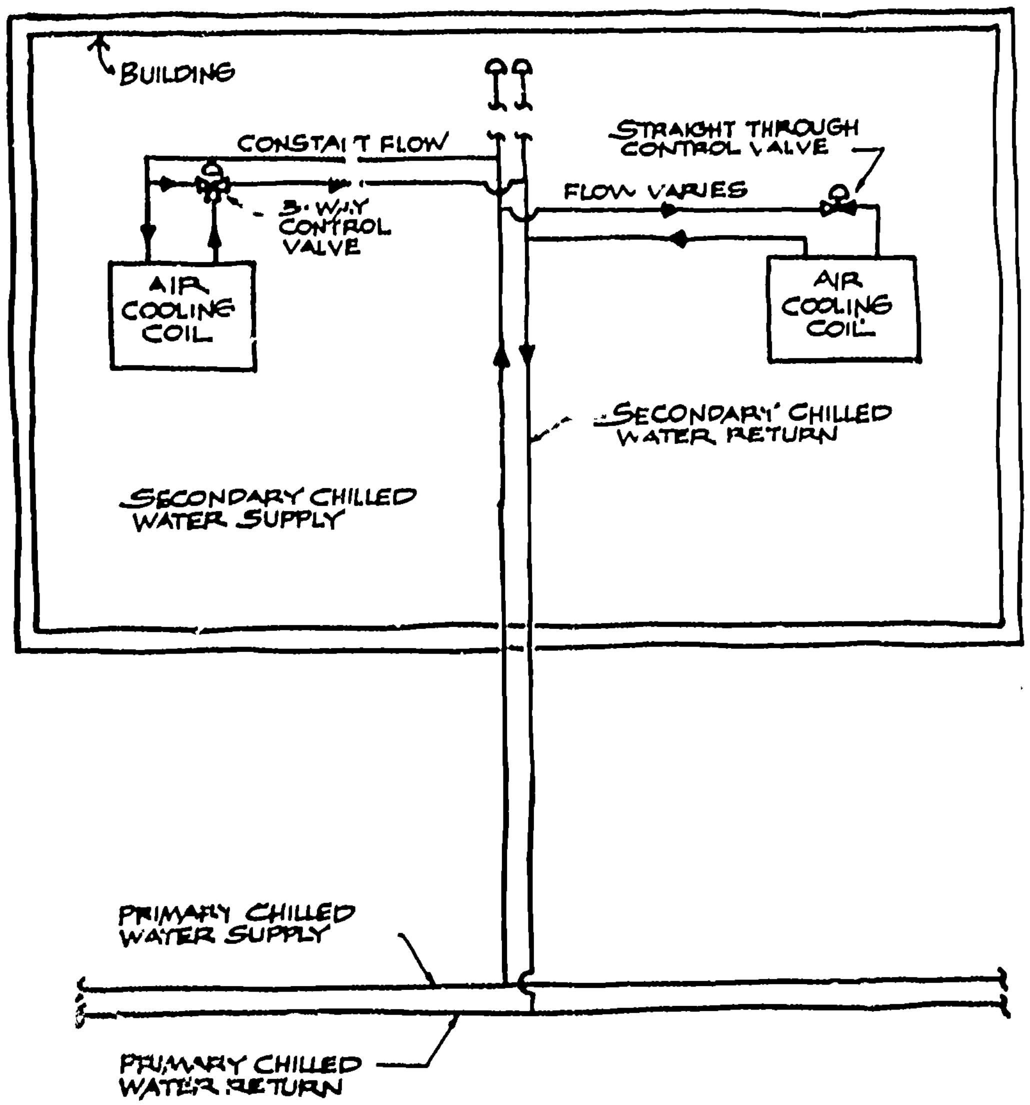


FIGURE 14. MIXED PRIMARY CHILLED WATER SUPPLY WITH SECONDARY CHILLED WATER RETURN FLOW DIAGRAM

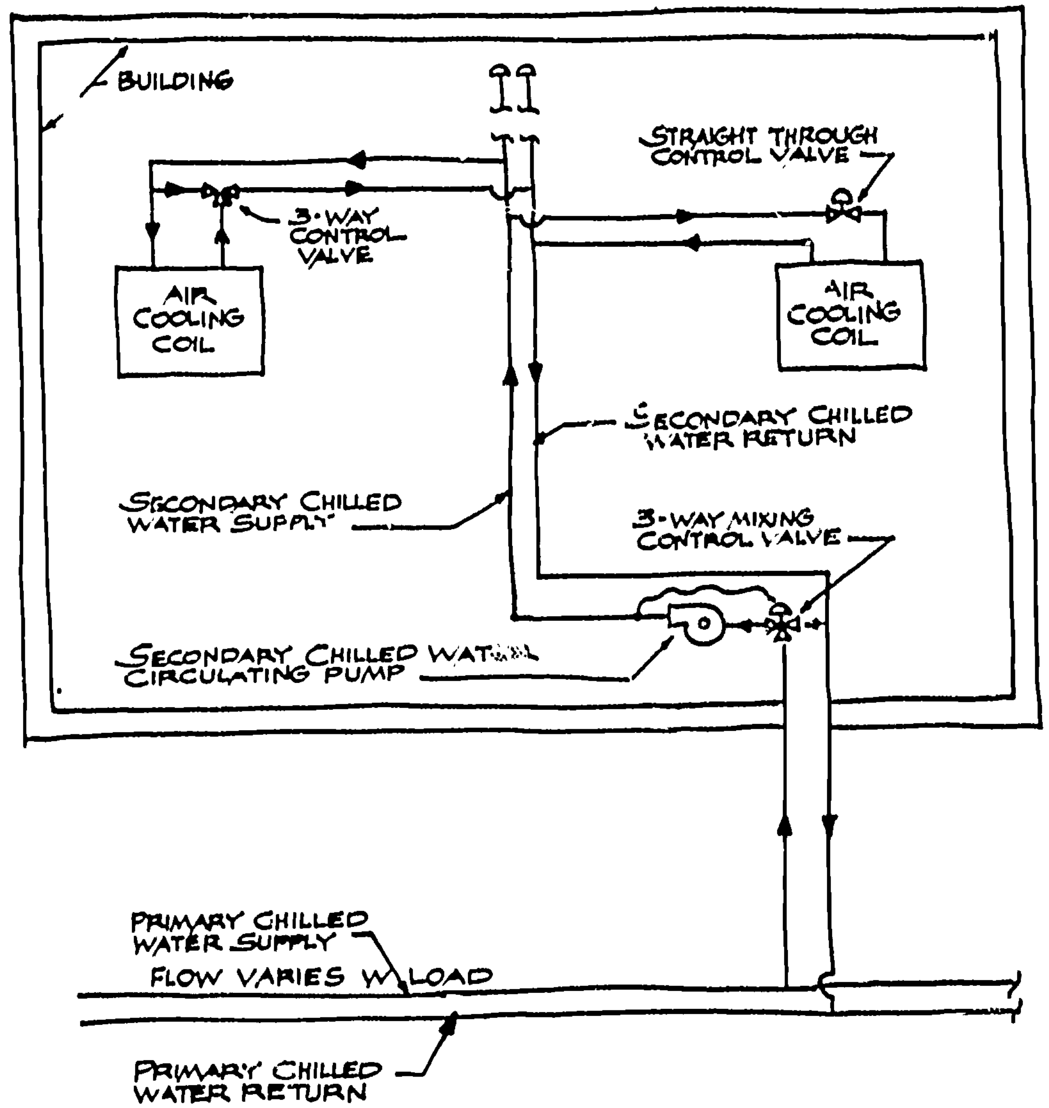
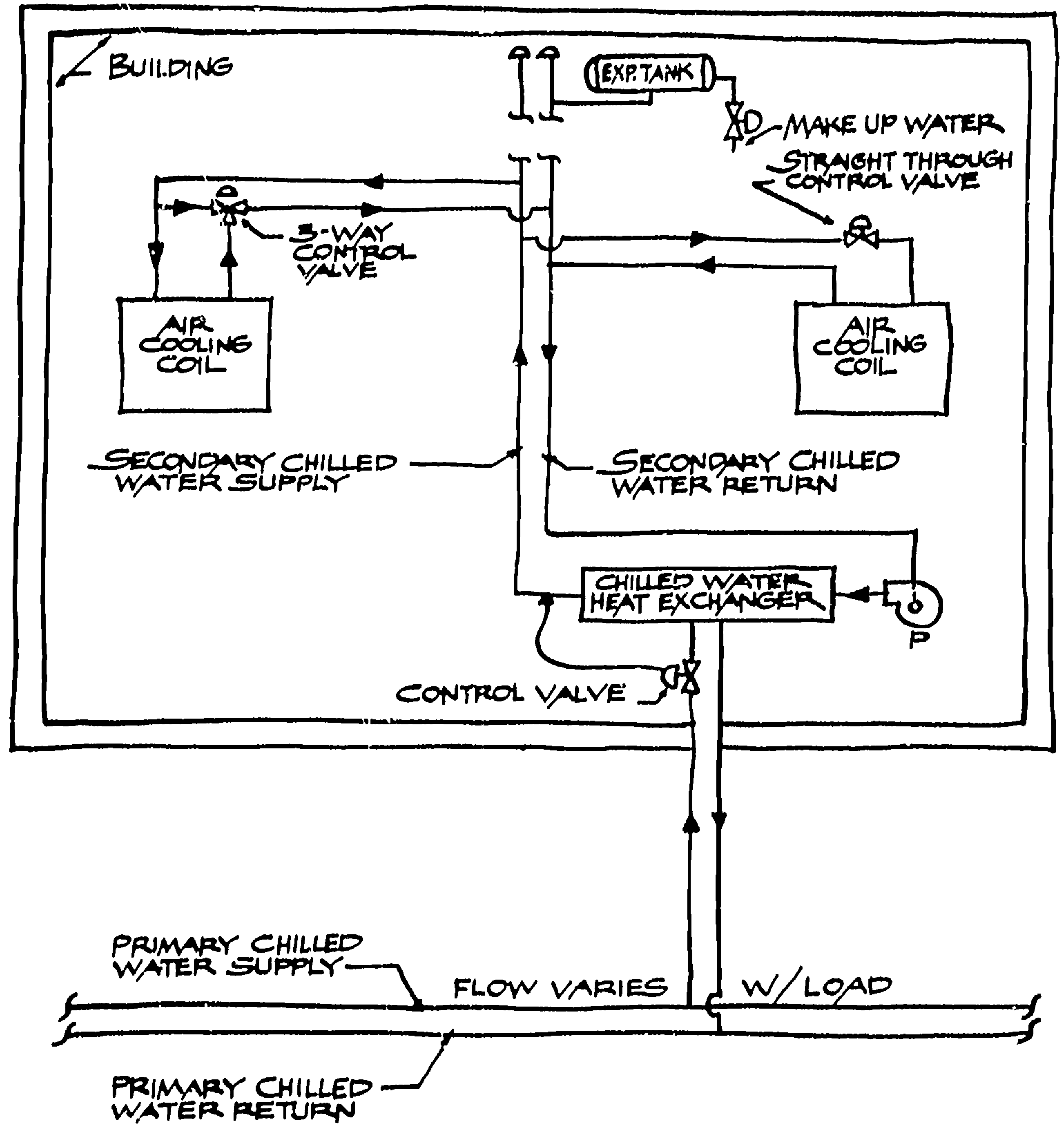


FIGURE 15. INDIRECT USE OF CHILLED WATER FLOW DIAGRAM



CENTRAL MONITORING SYSTEM

Consideration should be given in the operation of a central utilities plant to include a central control or monitoring system. This system can vary from the essentials of monitoring only the

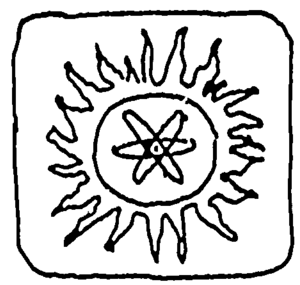
central plant equipment to the control of the complete campus air conditioning system including the equipment in the individual buildings. A completely instrumented system should include features to start-stop air handling and pumping equipment in each of the campus buildings, monitoring of air and water temperatures within the buildings; the ability to reset these to desired limits; and to generally control and monitor the important aspects of the entire air conditioning system.

The principal advantages include a reduction in operating labor, and more efficient operation of the systems resulting in savings in operating costs. Efficiency analysis of the system operation and preventative maintenance procedures can also be computerized as a further refinement.

Depending on the size of the system and the number of buildings, the cost for providing a central monitoring system will usually pay for itself in operating savings in five to ten years. The premium in additional first costs will be in the magnitude of 10-15% of the total installation cost.

Other controls are those normally required for the major items of equipment in the central utilities plant, such as chillers, generators and boilers, and the usual plant has a complete set of automatic indicating and controlling equipment for operation and protection of these major items of equipment.

TOTAL ENERGY PLANTS



One of the main advantages of a central utilities plant is the opportunity to improve plant efficiency by the utilization of larger equipment. This larger equipment and larger plant than would be possible in each of the individual buildings permits the use of more expensive and elaborate controls and also more heat recovery equipment. Although, it might be impractical to install pre-heaters and economizers on boilers in individual buildings, they become economically feasible in a central plant.

SECONDARY ENERGY

The greatest economy to be realized, however, is in the operation of the various major items of equipment in such a way as to make maximum use of secondary energy in what is commonly called a total energy system. Depending upon prevailing electric power rates in the community, it may be economically feasible to generate electric power for the campus. One of the major factors in determining this feasibility will be the degree to which the use of secondary energy from the power generation is utilized for space conditioning and many types of systems are possible. One efficient type of total energy plant utilizes high pressure steam turbine generators for generation of electric power with extraction or back pressure steam from the steam turbine being utilized for heating water for the campus heating water system and to drive turbine driven centrifugal chillers or serve steam absorption type chillers to provide the chilled water for the campus chilled water system. With this type of system, the heat rejected to atmosphere in the power generation cycle may be little or none, except for the boiler in-efficiency. The chief use of plant cooling towers will be for the rejection of heat from the chilled water system.

FLEXIBILITY

Flexibility can be designed into such a system. For example, steam turbines driving electric generators with low pressure steam extracted, can be provided with steam condensing equipment so that this unit may be operated straight condensing when power is required but low pressure steam requirements are minimum. Low pressure steam supplied from the turbine generators to the steam absorption type chillers for campus cooling can be supplemented through pressure reducing stations from the high pressure boilers in the event that sufficient low pressure steam is not available from the steam turbine generator during low electric power requirements. When

both heating and cooling are accomplished with low pressure steam, the low pressure steam requirements will generally follow the same load curve as the electric requirements. However, weekends and vacation times produce unusual load requirements and flexibility in such a plant is extremely desirable. In some plants cooling tower cells can be interconnected with their pumping systems piped to serve condensing units for either steam turbine electric generating units or, alternately, steam absorption type chillers to provide flexibility for load swings. This will usually result in a reduction of the number of cooling tower cells required and lower initial plant cost, as well as lower operating costs.

GAS TURBINES

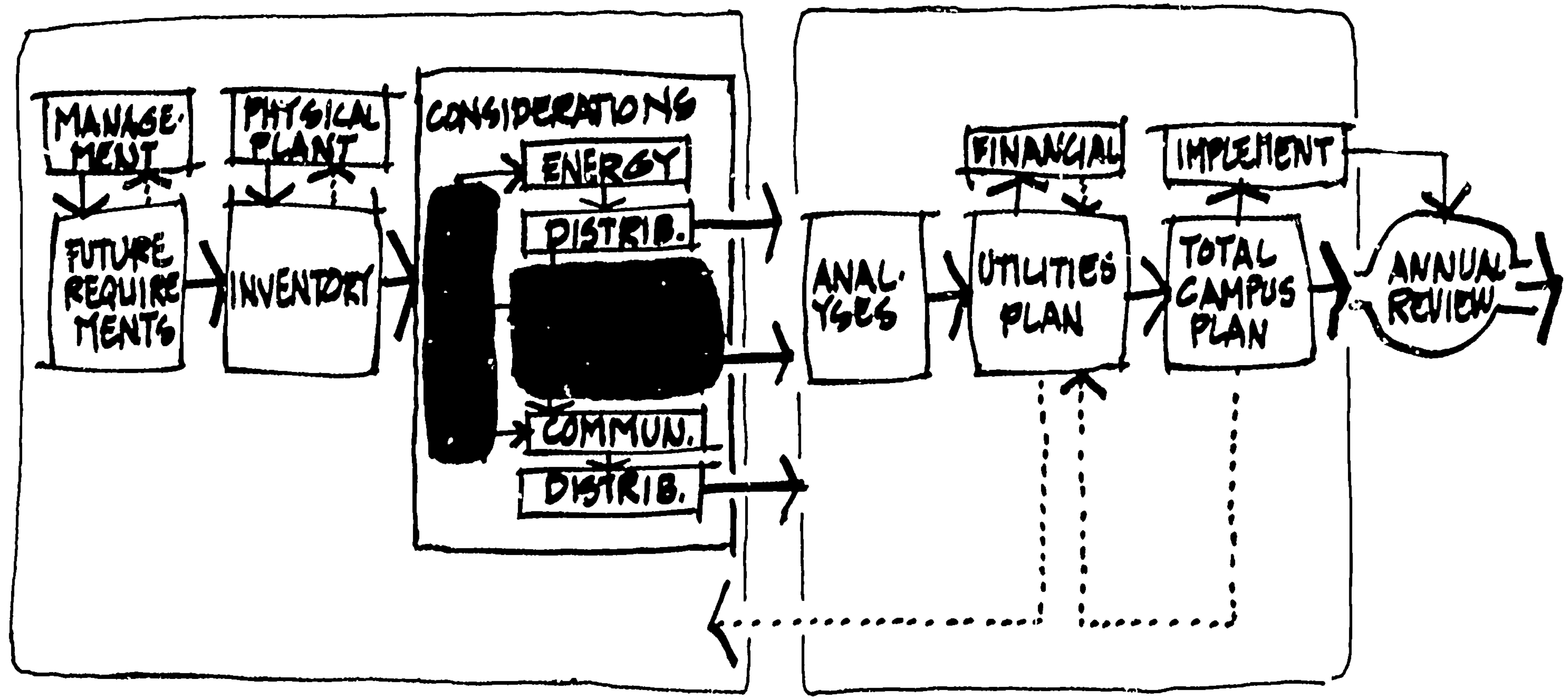
Other total energy systems would include gas turbine electric power generation, utilizing recoverable heat boilers, producing steam to drive additional steam turbine electric generators or centrifugal chillers or steam absorption type chillers to utilize secondary energy. This type of installation may have slightly higher initial cost than the previous one discussed, but may also result in higher thermal efficiencies for the plant as a whole with consequent lower operating costs.

ENGINES

For smaller central utilities plants engine driven equipment can be utilized for driving electric generators and refrigeration units, and their heat rejection utilized for secondary purposes such as space conditioning. This type of plant may have low initial cost and high efficiency, but will have higher maintenance costs than the previous two.

The ultimate choice of system as described above will vary with the individual campus and size of campus and should be determined by a complete feasibility study, including projections of power, building space and heating and cooling loads.

SERVICE UTILITIES



GENERAL

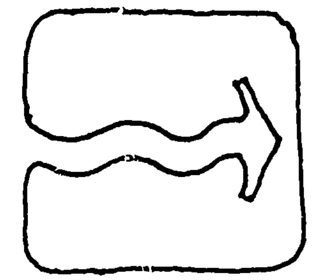
Service utilities include water supply, sewage disposal, area drainage, and occasionally compressed air distributed to buildings or an area. The cost of distributing these utilities such as water and compressed air varies with the distance between buildings, but the quantity of water and compressed air consumed is small and the cost of piping not a significant figure.

Variations in the cost of sewage collection and disposal systems from the campus buildings would not be a major factor in a decision regarding the location of buildings. The treatment of the sewage will probably be at a central collection point and a type of treatment will be selected depending upon the quantities involved, any provisions for future expansion, and any special treatment required due to unusual waste disposal requirements from campus facilities. Location of the treatment plant will probably be as remote as possible from other facilities on campus and in such a location as not to interfere with surrounding land utilization.

Surface drainage is almost completely independent of any other considerations on the campus except streets and parking lots. Its cost is influenced mostly by topography of the campus site and climatic conditions including annual rainfall and maximum rates of rainfall or other forms of precipitation.

In general, the service utilities do not greatly influence the planning of the campus. The design of the campus is usually influenced by factors other than service utilities but close coordination is required to assure proper function of the service utilities.

WATER SUPPLY



The use of water for the campus community is a function of the population including the students, faculty, residential, and on campus personnel. In general, planning of the campus water supply system requires the following determination:

1. Demand or maximum water requirement at any one time initially and projections for future demands over the planning period.
2. Source of the water.
3. Treatment of the water to make it potable and in some cases softening or additional treatment to improve the usability of the water.
4. Storage requirements to assure adequate supply of water at all times and for a reasonable time after failure of the source of supply and also to provide for fire protection.
5. An adequate distribution system to serve the initial and future buildings.

DEMAND

The amount of water required on the average and for peak demand is generally established by considering the following:

1. The population to be served including the student body, faculty and residential services which total number is usually multiplied by a factor.
2. Water requirements for research facilities.
3. Normal losses in the distribution system which is generally a percentage of demand.

4. Maximum requirements for fire protection.
5. Water required at central utilities plants or individual buildings for boiler and cooling tower make-up and other utility requirements.

There will be fluctuations in demand seasonally and with the rainfall cycle, and the peak demand will also vary from campus to campus depending on the general location and the character and climate of the campus.

SOURCES OF SUPPLY

The source of supply may be a local municipal system in some cases or other source of purchased water supply, or it may be by a campus owned system from either a ground water or surface water origin. Ground water is water below the ground brought to the surface by means of wells and pumping installations. Surface water is water taken from lakes, reservoirs or rivers. Availability and quantity of water from both sources of supply is dependent upon the amount of water used in the adjacent areas, the climate, the rainfall and other seasonal factors.

If ground water is the source of supply, consideration must be given to spacing of the wells so as not to have intersecting cones of depression and to the location of the wells relative to coast-lines where salt water intrusion may occur. Ground water has a disadvantage of generally being harder and higher in total solids than the surface water and may also contain dissolved gases. Well pumps generally require more horsepower but the location of the wells closer to the campus or even on campus may result in a net saving of pumping horsepower.

The use of surface water will involve an investigation of the lake or river to answer the following questions:

1. Is the yield of the drainage basin adequate?
2. What are the minimum yields to be expected?
3. What is the frequency of occurrence of minimum yield?
4. In case of reservoirs or lakes, what are the water losses due to evaporation or seepage?
5. What quantities of water are required to meet the rights of downstream users and what are the return rates on this stream?
6. What impoundment is required and of what size in order to assure equal rights to all water users from this source?
7. What is the impoundment requirement to satisfy demands during a maximum drought period?
8. Is there a suitable site for impoundment within economical distance of the campus?
9. What type of dam is best to impound the water?
10. What is the quality of the water?

If a natural lake is available, a hydrological study becomes desirable to determine the following:

1. The amount of rainfall and distribution of rainfall in the area.
2. Rate and frequency of rainfall.
3. Surface evaporation from both land and water.
4. Rate of infiltration of runoff.
5. Quality of water.
6. Pollution protection for the lake.

Economic factors affecting the decision on the use of ground water, surface water or possibly an available municipal supply would be the initial cost of wells or dams, pumps and interconnecting piping, and also the cost of pumping the water as well as treating it, all to be compared to the unit price of water from available supplies such as a municipal supply. Although surface water may be more economical to obtain and of better quality than ground water, its proximity to the campus may require long supply lines from the surface water source to the campus resulting in high pumping costs which could make it uneconomical.

TREATMENT

Samples of the available water from surface or municipal supply should be submitted to chemical analysis to determine the type of treatment required to produce a water quality suitable to the campus community. In the case of ground water, samples may be obtained from nearby existing wells owned by others, and the water quality evaluated prior to investing any capital in wells. The water should conform to the quality criteria of the State Department of Health and the U.S. Public Health Service drinking water standards. The following Figure lists common impurities found in water and indicates the type of treatment required to remove the impurities. Ground water supply may be excellent water and require little or no treatment except chlorination. On the other hand, it may be high in dissolved solids and gases and high in minerals with a resulting high hardness requiring extensive treatment.

Surface water is almost always of a reasonably high quality and very low hardness. The main difficulties normally encountered are turbidity and, on occasion, hardness due to the area which the stream has traversed. Chlorination is usually required to meet health standards. It is advisable to seek consultation with water treating specialists who will analyze water samples and make recommendations on treatment.

IMPURITY	UNDESIRABLE EFFECTS	METHODS OF TREATMENT
TURBIDITY	Makes appearance of water unsightly. Contributes to deposits in water lines, process equipment, boilers, etc.	May be improved by additions of coagulants, settling and filtration.
COLOR	Makes appearance of water unsightly. It will hinder precipitation methods such as iron removal.	Color removal can present a difficult problem. Coagulation, filtration, and chlorination.
HARDNESS	Contributes to deposit of scale in heat exchange equipment, boilers, and water lines.	Lime-Soda softening or Zeolite process.
CARBON DIOXIDE	Promotes corrosion in water lines, steam and condensate lines.	Can be controlled by aeration and deaeration. Neutralization can be accomplished with alkalies.
pH	High pH values contribute to pipe scaling and low pH values contribute to pipe corrosion.	pH can be adjusted by chemical additives.
IRON	Discolors appliances and plumbing fixtures. Causes deposits in water lines, boilers, etc.	Aeration, sedimentation and filtration through sand beds. Lime softening before sedimentation may be necessary.
MANGANESE	Same as iron.	Same as iron.
HYDROGEN SULFIDE	Cause of offensive "rotten egg" odor. Creates corrosive atmosphere in pipes.	Can be controlled by aeration and chlorination.
DISSOLVED SOLIDS	High concentrations of dissolved solids cause process interference and foaming in boilers.	May be reduced by lime softening and cation exchange by Hydrogen Zeolite.
SUSPENDED SOLIDS	Suspended solids cause deposits in heat exchange equipment, boilers, etc.	May be improved by additions of coagulants, settling, and filtration.

FIGURE 16. **WATER IMPURITIES AND METHODS OF TREATMENT**

STORAGE

Ground and/or elevated water storage are usually necessary for the following reasons:

1. To provide the quantity of water available for use in the event of well failure or reduced production due to the inability of the aquafers to meet the demand over sustained pumping periods.
2. To equalize pumping rates.
3. To provide constant pressure on the distribution system.
4. To provide large quantities of water readily available for fire fighting purposes at higher than normal usage rates.

It is usually recommended that ground storage capacity be equal to daily requirements at the average rate of use and elevated storage capacity be of approximately 10 hours supply. The elevated storage has the additional benefit of maintaining the desired head on the water distribution system in the event of failure of all pumps. Ground storage is generally located adjacent to the circulating pumps. Elevated storage should be located in the approximate center of the service area in order to equalize pressure to all feeders.

DISTRIBUTION SYSTEM

The water distribution system includes all of the pipes, valves, hydrants, and appurtenances for conveying water from the sources to the ultimate users. This system of piping is generally laid out in a circle, a grid, or a tree system or a combination thereof and quite often simply follows the campus road and street layout.

The adequacy of a distribution system is determined by the pressure that exists at the various points in the system under normal conditions of operation. The pressures must be sufficient to serve the domestic users and the fire demand but they should not be unnecessarily high. Since

the major cost of a water system is in the distribution, it is essential that it be designed economically. The distribution mains and branches are generally sized on the basis of pressure loss per unit length for the expected normal flows, including a normal fire fighting flow, and considering pipe friction. In the selection of pipe sizes, the following factors should be used:

1. Pipes smaller than 4 inches in diameter are used only when no fire flow is involved. The National Board of Fire Underwriters recommends a minimum size of 8 inch diameter pipe but will accept 6 inch diameter pipe in grids when the lengths between connections are not over 600 feet.
2. Pipe should be interconnected at intervals of 1200 feet or less.
3. Multiple mains are more desirable than single large mains as improved reliability is obtained (allowing line breakage without totally disrupting service to areas).
4. Fire hydrants should be placed at street intersections at the most effective locations. When blocks are long and the class of fire risk is high, fire hydrants should also be placed between street intersections. A map of hydrant locations should be prepared and posted at the central utilities plant and at the fire station.
5. Adequate block valves should be provided throughout the system so each portion of the line can be isolated for repair by closing two valves.

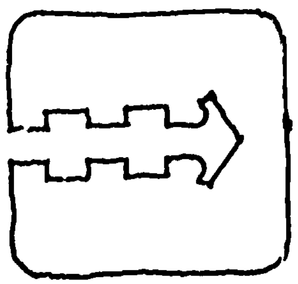
FIRE PROTECTION

In order to provide proper pressure for fighting fires, water systems are generally operated by constantly maintaining full fire pressure in small supply systems or by maintaining a lower normal operating pressure and, when needed, by increasing pressure for fire fighting through increased pumping at the pump station. Alternately, increased fire fighting water pressure can be obtained through mobile pumping engines drawing water from hydrants near the fire. The proper pressure for fire protection is usually expressed in terms of the pressure required at the nozzle of the fire hose. The National Board of Fire Underwriters recommends 75 pounds per square inch for 10 or more buildings which exceed three stories

in height, 60 pounds per square inch in localities with fewer buildings, and 50 pounds per square inch in thinly built-up districts. When pumpers are used, a minimum pressure of 20 pounds per square inch at the hydrants is recommended.

For proper fire protection it should be possible to discharge a 175 to 250 gallons per minute stream with a pressure at the base of the nozzle between 40 and 100 pounds per square inch. For campus and residential areas it should be possible to direct not less than 4 such streams on any building from hydrants located in the immediate area.

SEWERAGE



The area to be served by the sewage collection system is basically the same as that served by the water distribution system. As growth occurs, trunk sewers are needed to serve projected growth areas to which lateral sewers are then connected as actual development materializes.

FLOW RATES

Studies indicate that the sewage flow varies from 60 percent to 130 percent of the water delivered to the water distribution system, depending on the amount of infiltration. These flow rates are made up of present and probable future quantities of campus sewage and ground water infiltration. Using population estimates, campus enrollment and projected land usage, an average

per capita sewage flow can be computed. Historically, this per capita figure has increased in recent years due to automatic appliances which have larger water consumption rates, including improved plumbing fixtures.

In designing a sanitary sewer, the determination of flow quantities requires consideration of the following:

1. The design period, i.e. the time in which peak or maximum design flow occurs.
2. Per capita sewage requirements.
3. Contributions from commercial areas surrounding the campus.
4. Infiltration of storm water where combination sewers are used. This practice should be discouraged, however.
5. The presence of ground water and possible infiltration through joints and connection points.

DESIGN BASES

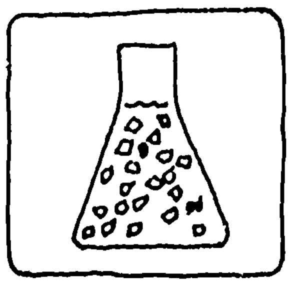
In designing a sewage system the following should be kept in mind:

1. Sewers must be deep enough to receive the flow from all sources.
2. The material from which a sewer is made should be resistant to corrosive action and scouring.
3. The structural strength of the sewer should be sufficient to carry backfill impact and expected live load satisfactorily.
4. The size and slope or gradient of a sewer should be adequate for the flow to be carried and the slope must be sufficient to avoid depositing solids.
5. The sewer joint material must be selected to meet the conditions of use.
6. Manholes, junction chambers, and other structures must be designed to minimize head loss and settlement of solids.

In order to prepare the hydraulic design of a collection system, a map should be prepared showing the location and length of all required sewers and profiles of the ground surface along each line with critical elevations. As part of a collection system, lift stations may sometimes be required. These should be avoided if possible. The need and location of a lift station is dictated by topography of the area and the location in relation to the sewage treatment plant.

If a lift station is necessary, it should be accessible in all types of weather and should not be subjected to flooding. It should be located as remote as possible from populated areas. It should be provided with adequate storage of sewage in the event of a breakdown or power failure and all mechanical equipment in the lift station should be duplicated to permit effective operation and reliable performance.

SEWAGE TREATMENT



The determination of the sewage characteristics is essential to the proper design of any treatment system. For existing campuses being expanded it is desirable to have a laboratory analysis made of the sewage, including tests to determine the following characteristics:

1. Suspended solids both fixed and volatile.
2. BOD (Biochemical Oxygen Demand)
3. pH (Degree of Acidity or Alkalidity)
4. Dissolved Solids
5. Presence of any greasy and oily matter.
6. Affinity for chlorine.

Other laboratory determinations such as the presence and quantity of nitrogen compounds and metallic elements may be required. Any knowledge of any special industrial wastes or animal

wastes should be investigated as to their effects and the proper treatment required for them.

The degree of treatment required for sewage is usually based upon the ability of the receiving waters to accept treated waste and still retain their uses. The following factors should be considered in determining the ability of receiving waters to accept treated waste:

1. The rate of flow of the receiving water.
2. The existing or potential use such as water supply, industrial or recreational.
3. The effect of seasonal variations on the receiving water.
4. State codes and regulations concerning pollution of the receiving water.

The disposal of plant effluent on land may be practiced where suitable receiving water is not easily accessible. Such disposal requires relatively large areas with a low ground water level and a soil suitable for percolation.

Upon occasion the plant effluent may be used for irrigational crops or to recharge ground water reservoirs. Also, industry with water requirements which can be met by treated effluent can sometimes use this in a manner mutually beneficial to the community and industry.

Treating requirements may vary seasonally due to changes in the composition of the raw sewage, changes in the capacity of the receiving waters and changes in the use of the receiving waters. Sewage treatment processes may generally be classified as follows:

1. Primary treatment. This type of treatment is usually expected to remove 50-60% of the suspended solids and 25-35% BOD.
2. Secondary treatment. This stage of treatment using conventional biological processes may remove up to 90% of suspended solids and 75-80% BOD.

The following Figure presents a comparison of treatment characteristics of various types of biological treatment plants.

TYPE OF PROCESS	BOD REMOVAL	POUNDS BOD REMOVED PER 1000 FT^3	HOURS AERATION REQUIRED	AIR REQUIREMENTS CF/#BOD REMOVED	COMMENTS
Activated Sludge	90% to 95%	35	5 to 6	1000	1) High initial oxygen demand
High Rate Aerobic	60% to 70%	100	24 to 72	800	1) Required 3 times air of conventional activated sludge plant.
Extended Aeration	70% Average	30	24 to 30	2000	1) BOD Removal widely variable
Modified, Tapered, or Step Aeration	90% to 95%	40 to 50	1	350 in Contact Area 750 in Stabilization Area	1) Less than 1/2 the aeration tank capacity normally required. 2) Not sensitive to shock leads. 3) Odor free.

FIGURE 17 **COMPARISON OF TREATMENT CHARACTERISTICS OF VARIOUS TYPES OF BIOLOGICAL TREATMENT PLANTS**

The choice of processes to meet certain treatment requirements is effected by an evaluation of the following factors:

1. Sludge disposal and the area available at the prospective plant site.
2. Proximity to built-up areas.
3. Topography versus hydraulic requirements.
4. Quantity and quality of sewage.
5. Sludge from each process.
6. Availability of qualified operating personnel.

In recent years, considerable development has occured in discovering chemical additives which can be used to assist in sewage treatment. It is expected that further development of these additives may simplify sewage treatment.

An important factor to be evaluated in selecting the method of treatment is the overall cost. Total cost should be determined for each process including initial construction cost and operating cost compared on an annual basis and based on the calculated life of the improvement. The following Figure presents national average costs for various types of facilities for the flows listed.

Prior to disposal of domestic waste it is usually necessary to obtain a permit from the State Board having authority. The following items of information should accompany each application for a permit or for an amendment to an existing permit:

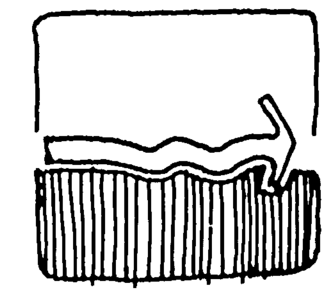
1. A copy of a public announcement that such a filing is being made.
2. A list of property owners having tracts of land downstream or in the vicinity of the point of discharge.
3. A map or plan of the area showing the location of the disposal system from the point of discharge and ownership and location of tracts of land downstream and in the vicinity of the discharge.
4. A brief description of the treating plant including the main components.

Most states also require submittal of complete plans and specifications for the construction of the sewage facility for approval of the State Department of Health.

FIGURE 18 **RELATIVE CONSTRUCTION COST BASED ON FLOW**

TYPE OF PLANT	DESIGN FLOW IN MGD	AVERAGE COST	VALID SIZE RANGE IN MDG	PLANT PROCESS DEFINITION
Imhoff-Type Plants	0.1 1.0 10.0	$ 60 300 1500	0.095 to 1.100	A form of primary treatment employing a two-story tank consisting of an upper sedimentation chamber and a lower digestion chamber, with some type of mechanical equipment.
Primary Treatment Separate Sludge Digestion Plants	0.1 1.0 10.0	80 300 1050	0.40 to 10.00	A form of primary treatment which employes a separate structure for digestion of sludge.
Stabilization	0.1 1.0 10.0	23 80 300	0.01 to 4.50	A pond designed for the treatment of sewage by natural aerobic processes, with or without the addition of supplemental aeration or chemicals.
Activated Sludge Plants	0.1 1.0 10.0	70 400 2200	0.015 to 4.000	A secondary treatment process which brings settled sewage into contact with biologically active sludge in the presence of excess oxygen.
Trickling Filter-Separate Sludge Digestion Plant	0.1 1.0 10.0	100 350 1300	0.10 to 5.00	A secondary treatment process, following primary treatment, using a bed of coarse material over which the settled sewage is distributed, followed by final clarification.
Trickling Filter-Imhoff-Type Plants	0.1 1.0 10.0	70 350 1600	0.10 to 1.00	Identical to -trickling filter- separate sludge digestion, but employing Imhoff-type treatment for the primary phase.

SURFACE DRAINAGE



The area to be served by the surface drainage system may be entirely different from the one served the water and sewage collection systems. It will probably comprise all of the area of the above systems plus other adjacent land from which runoff onto the campus area may occur. A surface drainage system consists of the facilities to collect and dispose of the surface runoff from storm rainfall and the drainage area or water shed tributory to the system. Surface drainage facilities include swales, gutters, ditches, channels, underground pipes, inlets, manholes, junction boxes, bridges, erosion control structures, detention ponds and pumping stations.

There also may be a sub-surface drainage system consisting of facilities to collect and dispose of water that occurs below the ground surface which constitutes a threat to health or to the stability or maintenance of structures, pavements or utilities. Sub-surface drainage facilities include open jointed, perforated, or porous collector pipes, risers, clean-outs, outlet structures and other pertinent works.

CHARACTERISTICS

Characteristics of a drainage area water shed to govern the amount and rate of runoff are:

1. Kind and extent of vegetation or cultivation.
2. Soil conditions.
3. Steepness and length of slopes.
4. Size and shape of water shed.
5. Number, arrangement, slope, and condition of drainage channels or water shed.
6. Types and locations of existing drainage structures and water shed.
7. Historic annual and instantaneous rainfall rate.

AREA DETERMINATION

The area tributory to any point under consideration in the drainage system must be determined and boundaries or drainage divides must be established by field surveys, a suitable topography map, or by aerial photographs. The complete drainage area of a water shed must be divided into component parts contributory to each point of inlet. This generally requires a preliminary layout of sewers and tentative location of inlet points. System layout and inlet locations are often rearranged as design proceeds and component parts of the main drainage area are revised accordingly.

The drainage area survey should include the following information:

1. The present and predicted future land use and its effect on the degree of protection provided.
2. The degree to which all contributory areas are impervious.
3. The character of soil uncovered and its effect on the runoff coefficient of the area.
4. The general magnitude of ground slopes and their effect on the time of concentration.

RAINFALL INTENSITY

Determination of rainfall intensity for storm sewage design involves determination of the following:

1. Average frequency of occurrence.
2. Intensity-duration characteristics of a given average frequency of occurrence.
3. Time required for runoff from the most remote part of the drainage area to reach the point under design.

The average frequency of rainfall occurrence used for design determines the degree of protection afforded by a given storm sewer drainage system. Cost-benefit studies are not usually conducted for campuses, but the cost of protection should be consistent with the amount of damage prevented.

The use of average rainfall intensities is not foolproof. Flash floods may result in inadequate system performance. However, the occurrence of flash floods may not justify the increased cost of a larger collection system particularly if no damage occurs other than inconvenience.

SURFACE RUNOFF

The system to handle this runoff may in addition to underground piping and collection in storm sewers include open channels. Open channels range in form from graded swales and ditches to very large channels of rectangular or trapizoidal cross section. Swales are usually used for surface drainage of graded areas around buildings, and they are usually triangular in cross section with very flat side slopes. Normally no detailed calculations on their flow carrying capacity are necessary.

Ditches may be used for collection of surface water for larger areas and along road shoulders.

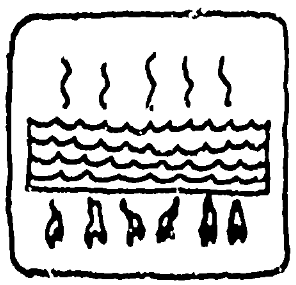
Larger open channels are usually used for main collectors of large areas. Whether or not the channel is to be lined depends on erosion characteristics, grades, maintenance practices, space and other factors including cost.

In open channel flow, water velocity must be carefully calculated in order to establish to what extent the water course may be subjected to erosion or the deposit of sediment. Channel velocities can be

controlled by the provision of drop structures or energy dissipators, widening the channel, or by increased depth.

The channel can be lined with turf, asphaltic or Portland cement concrete or ungrouted or grouted rubble to control erosive flows. The choice of material depends on the velocity and turbulence involved, the quantities, availability and installed cost of materials.

DOMESTIC HOT WATER



The needs of the campus for domestic hot water are many and varied. In general, laboratory and home economics departments may be large users of hot water; also, dormitories, the main kitchens and cafeterias and campus laundries.

This hot water supply may be from a central utilities plant with a distribution system to the individual buildings, or it may be provided by hot water heaters in each individual building, or by a combination of these two. The temperature of the water will vary according to the usage, as will also the quantities, and these are shown in the following Figure.

FIGURE 19. DOMESTIC HOT WATER DESIGN CONSIDERATIONS

	TYPE FIXTURE	WATER DEMAND	TEMPERATURE REQUIREMENTS	REMARKS
DORMITORIES	Showers	3 gpm each max.	130° F	Allow 6 gallons per occupant per hour.
	Lavatories	1.5 gpm each max.	130° F	
	Service Sinks	4 gpm each max.	130° F	
CLASSROOM BUILDING	Lavatories	15 gph	130° F	

	WATER DEMAND PER CONSUMER	TEMPERATURE REQUIREMENTS	REMARKS
CAFETERIAS	1.0 gallons per minute	130° F	Equipment including all food preparation items, automatic dishwasher and scullery equipment, for 4000 or more consumers.
HOSPITALS	0.80 gallons per minute	130° F	All hospital services imposing a hot water demand generally are adequately served at a rate of.
	0.50 gallons per minute	180° F	

All miscellaneous other occupancy types using general fixtures can be calculated based on the above data.

TYPES OF HEATERS

The type of heater to produce the hot water could be one or more of the following:

1. Instantaneous heaters where the water is heated and used with no storage provided. This type of heater would have a limited application for campus use confined generally to lavatories in educational buildings.
2. Storage type heaters in which water is heated continuously or intermittently as desired to maintain the storage water temperature.

The volume of storage required will have a definite relationship to the hourly heating capacity (recovery rate) of the heater. The required storage volume increases with a reduction in the recovery rate of the heater. When the recovery rate of the heater is equal to the maximum peak demand, no storage may be required.

DIRECT HEATER

A direct heater is one in which water is heated by being passed across a metal surface on the other side of which there is a burning fuel or hot combustion gases. This method of heating water is simple and utilizes fuel directly, but requires venting which may present problems. Scaling on the water side is another problem of this type of heater due to the high temperature of the heating surface.

INDIRECT HEATER

An indirect heater heats water by passing it across a metal surface on the other side of which there is hot water or steam. This method permits closer control of temperatures than direct

firing. It generally is more costly. However, no venting is needed and space requirements are flexible.

CENTRAL PLANT

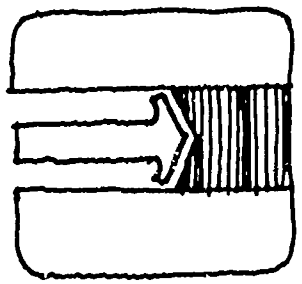
Generally, in the central utilities plant there will be steam or high temperature hot water available for piping to heat exchangers in the individual buildings. Alternately, a converter or heat exchanger can be used in the central utilities plant through which hot water is piped to the individual buildings. This normally would require a recirculating system in order to assure hot water at the end of the run. In most cases a central system in a central utilities plant would be used only to serve the major consumers of domestic hot water such as laundries and mess hall kitchens. The smaller users would be provided with an individual hot water heater in each building utilizing either electric heat or direct fired heaters.

The advantages of central systems would possibly be fuel savings, less maintenance and supervision and a ready source of energy at the utilities plant. Disadvantages would be a high first cost for the distribution system plus the pumping requirements.

Often individual buildings are provided with heat exchangers served by high temperature hot water or steam from the central utilities plant. The building heating water system may sometimes be used for heating hot water if the water temperature is not required to be higher than the heating water temperature.

Cost comparisons should be prepared for supplying domestic hot water by two or more of the above methods and the best system utilized.

COMPRESSED AIR



Compressed air is used on a college campus for purposes including the following:

1. Pneumatic Control Systems.
2. Airlift Water Pumping.
3. Agitation in Sewage Treatment.
4. Air Motors and Pneumatic Tools.
5. Laboratory Use.
6. Pneumatic Tube Systems.
7. Industrial Shops.

PRESSURE

The pressure of the compressed air will vary widely depending upon the requirements. It ranges from 25 pounds per square inch to several hundred pounds per square inch. The quantity is measured in cubic feet per minute of free air at atmospheric conditions. In general pressure classifications are as follows:

Low Pressure	Atmospheric to 125 psig
Medium Pressure	126 to 399 psig
High Pressure	400 to 6000 psig
Vacuum	Below atmospheric

Vacuum pumps may be considered a special case of air compression and their use is largely confined to laboratories. Generally small vacuum pumps are provided for individual laboratories rather than a campus wide vacuum system.

The quality of the compressed air required is established by the use to which the compressed air is placed and the cleanliness necessary. Water and oil contamination are sources of trouble and hazard. Moisture must be removed to a degree required by the usage.

CENTRAL PLANT

If a central utilities plant is used and a distribution tunnel is available, compressed air may be supplied from this source. The advantages of a central system are probably lower first cost and reduced operating and maintenance cost. The only disadvantage would be the high distribution cost depending on the extent of the distribution system required. In this case consideration should be given to individual building systems.

For localized needs electric motor driven air compressors with automatic pressure controls, storage tanks, and distribution systems are installed close to the point of usage. The primary advantage is a lower first cost in some cases, but operation and maintenance cost will be higher than in a central plant. Also there can be a noise nuisance depending on the location of the equipment.

COMPRESSORS

Compressed air is obtained normally from an air compressor taking air at atmospheric pressure and compressing it to some higher pressure in one or more stages. This compressor may be reciprocating, rotary,

or centrifugal and it may be air cooled, water jacketed or have devices for precooling, after cooling and sometimes inter-cooling if more than one stage of compression is used.

Compressors are normally direct connected to an electric motor or gas engine or may be connected through a fluid drive or gear. Reciprocating compressors are usually V-belt driven. Booster compressors handle air at a higher than atmospheric pressure and compress it to a still higher pressure. Booster compressors are normally used to produce small quantities of air at high pressure from a large compressed air supply at a lower pressure.

AIR COOLERS

Heat exchangers are normally used to cool the air as follows:

1. Pre-coolers are used to increase the volumetric efficiency of compressors by reducing the volume of the air mass and increasing mass flow. They usually are water cooled with condenser water or chilled water.
2. Inter-coolers are used to reduce the heat of compression of air between the stages thus decreasing the work of compression. In small compressors cylinders and motors are cooled by air circulation from a fan usually built into the fly wheel of the compressor.
3. After-coolers are used to remove moisture from the air and also to reduce expansion and contraction of distribution lines. After-coolers are generally water cooled.
4. Preheating air is not normally required but may be employed on the air intake to prevent freeze ups in cold weather. In some cases where it can be economically justified, air from the distribution system is reheated to about 250 degrees thus resulting in a volume increase of 30 to 35 percent. The reheat increases the work done by pneumatic tools' and prevents moisture freeze-ups.

INSTALLATION

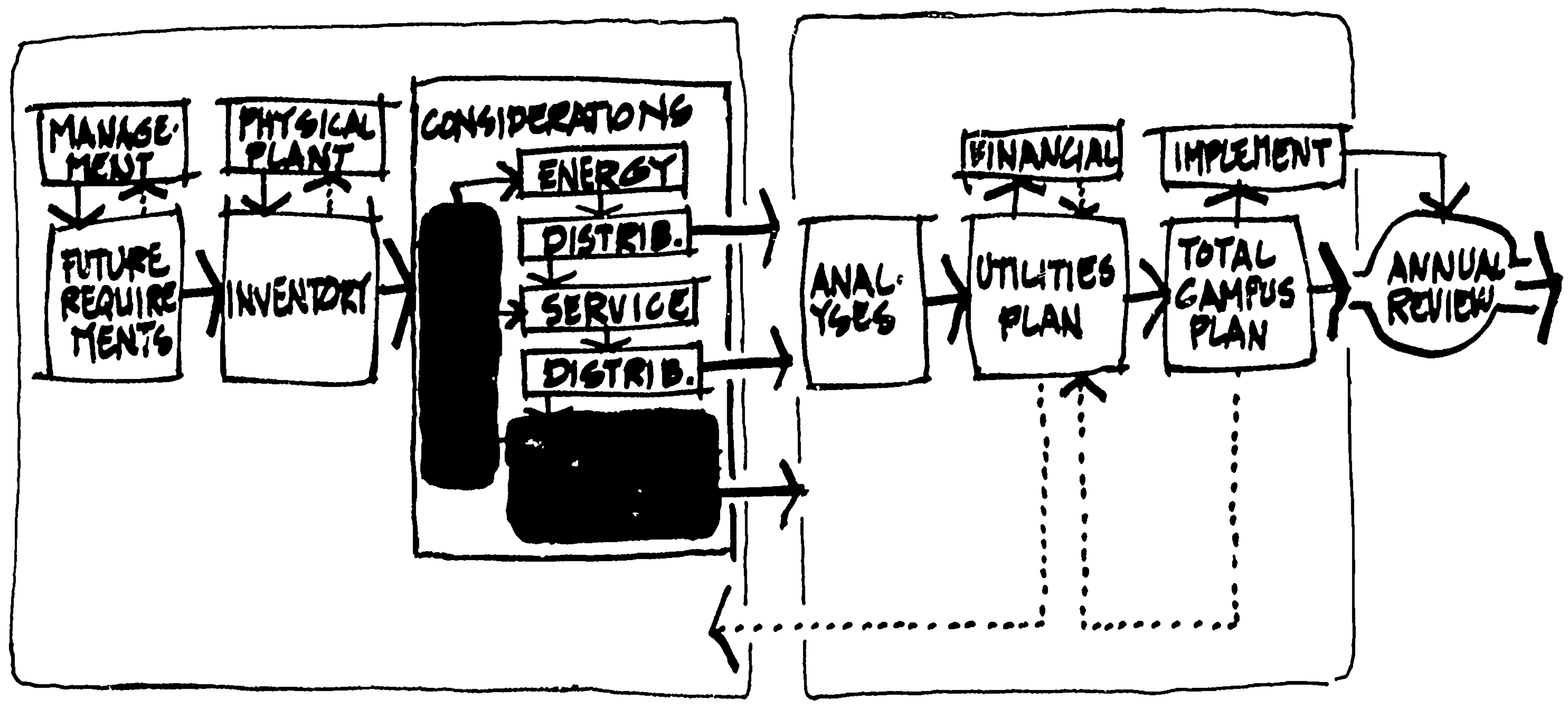
Frequently storage tanks are used to store air between the compressor and the distribution system to accomodate peak loads and reduce cycling of compressors under automatic control.

The intake pipe to the compressor should be in a cool location, generally extended 8 to 10 feet above ground level, hooded and screened. All piping of compressed air should be installed to drain away from the compressor and low points should be trapped to remove moisture. Air filters may be required on the compressor intake and air-dryers may be required on the discharge.

Compressors are usually operated with automatic pressure control which will cycle the compressor to maintain pressure on the receiver or storage tank.

When planning a campus compressed air system a cost analysis should be made of the use of individual building air compressors versus a central air system to arrive at the most economical owning and operating cost and best system.

COMMUNICATIONS UTILITIES

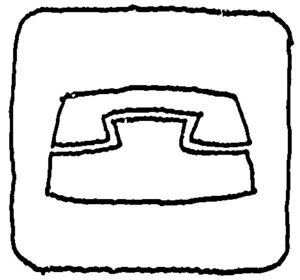


GENERAL

Communication systems on a campus do not normally influence arrangements of facilities since most major items of equipment are in the individual buildings and the interconnecting wiring is relatively inexpensive. However, once the campus building arrangements have been established and the various energy utilities planned including routing of tunnels and walkways, a thorough planning of the means of communication between buildings should be initiated.

On any campus the demand exists for rapid and sometimes instant communication between buildings, departments, functions, administrative personnel and maintenance and security personnel. The need for this communication ranges from relay of personal conversations to making emergency announcements. Engineering has developed many systems of visual, audio and mechanical means of communication such as television, radio, and teletype systems. Recent developments include microfilm scanning, data retrieval systems, computers, and closed circuit television systems with printers. Pneumatic tube carriers are still frequently used and have their special applications. Each system has its advantages and disadvantages which will depend on the intended function or use.

TELEPHONE



Day to day operation of a university depends not only upon communication between its major departments and buildings, but also with the outside world. In general, personnel in administrative offices, teachers offices, shops and maintenance offices, cafeterias and athletic departments require telephone service to outside of the campus. Additionally, there should be conveniently located pay telephone booths for student use as well as telephones in the individual dormitories. Telephones may also be used for paging, for conferences, for central dictation to machines and for access to data processing machine services.

PROPRIETARY SYSTEM

Telephone systems for exclusive campus use may be owned and operated by the school itself. The advantages of a proprietary system offer relatively low initial cost, simplicity of operation and low maintenance cost. It may also be connected through the school's intercommunication system and used for voice paging, conference and dictation.

The disadvantages of a proprietary system are as follows:

1. Cost of maintenance and new equipment must be assumed by the university.
2. An inventory of spare parts must be maintained.
3. The connection to exterior telephone lines is prohibitive in some cases and generally many offices will require separate telephone systems to outside lines in addition to the internal proprietary system.
4. Depreciation of equipment and replacement with more advanced and adequate equipment must be at the expense of the university.

PUBLIC SYSTEM

Alternatively, with the use of a public telephone system all telephone equipment and lines are the property of the public telephone company. These facilities are operated and maintained by the company and leased to the school for a contracted annual amount. The use of the public system has the following advantages:

1. Communication to outside or inside of the campus from any telephone.
2. Connection of separated parts of schools by one telephone system.
3. Maintenance by the telephone company.
4. Additional equipment without capital investment.
5. Outside fire and police connection from any point on the campus.

The main disadvantage to a public system may be its cost. In some cases the local private or municipal telephone company serving the campus area may be less than adequate. Generally, however, service from public systems is acceptable.

With the use of a public system the entire installation may be made by the telephone company at no cost to the university. This is generally the accepted way for most campus plans.

TYPES

The types of telephone systems are as follows:

1. Automatic. An automatic telephone system functions through a dial or selector switch to call other stations. When the call is internal, one, two or three digits are dialed. External calls require dialing one digit

for outside lines and then the number called. All systems are 24 volt dc powered from power packs or emergency circuits.

The advantage of automatic systems is that they connect telephones without service of an operator on interior calls and on calls to the outside from within the system. Usually automatic equipment affords a large number of simultaneous conversations, limited only by the number of outside lines available to the system. For interior calls the number of calls is limited to half the number of phones on the system.

The disadvantage of automatic systems is that they require operators for receiving exterior calls, unless the switchboard is designed as a separate exchange by the telephone company. Also, up to 400 square feet of space must be provided for power supply of switching and relay racks. Such equipment must be housed in a locked room having a controlled atmosphere.

2. Manual. An older and less costly type of system employs a switchboard and an operator for the handling of all interior and exterior calls. The advantage to this type of system is that the space requirement for equipment is less, control is exercised over long distance calls and very little maintenance is required. The disadvantage is that all traffic must go through the operator and a moderately sized school could create a volume of traffic which might be beyond the ability of a single operator to handle. Further disadvantages are that only limited service is available to the outside when the operator is off duty, and no interior service is available at these times.

DISTRIBUTION

Distribution for the telephone system, whether public or private may be by one or more of the following methods:

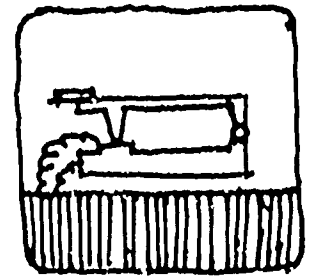
1. Aerial cable on poles.
2. Cable and rigid conduit run in utility tunnels or under covered walkways or in buried ducts.
3. Direct buried cable.

The most economical of the above is the aerial cable, but it is unsightly. Where utility tunnels exist, utilization of these tunnels will improve campus appearance with little difference in cost. Many telephone companies are changing to the use of cable in buried conduit.

For most campuses a proprietary system requires too much capital investment initially unless a very limited service to the outside is required. Usually, the public telephone system can best serve large campuses of many buildings and offices or divided campuses. The volume of traffic generated by the administration, the many instructional departments and by the maintenance department will justify this system. Moreover, capital investment for future expansion is made by the public telephone company and requires little further investment by the school.

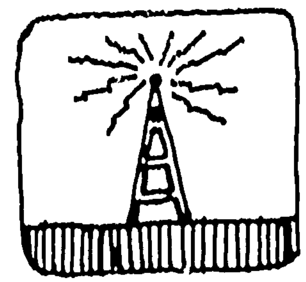
In planning for an adequate telephone system sufficient space should be provided in all buildings to house the required telephone equipment. These requirements may be obtained from the local telephone company.

TELEGRAPH



Telegraph systems for campuses are usually required at only one central communication center. The entire installation is usually made by the telegraph company. There is a monthly charge for rental of the required equipment. More than one receiving and sending machine can be installed if the volume justifies, or for convenience in more than one building but this will depend upon the individual campus requirements.

RADIO AND INTERCOMMUNICATIONS



Intercommunication for the campus may also be by a radio system or a wired intercommunications system. These systems may be used for paging, making announcements, and for general communication. They may either be wired or wireless.

INTERCOMMUNICATIONS

Wired systems usually have master systems located at central control points with slave stations or speakers at remote points such as classrooms, offices, corridors, assembly rooms, and maintenance areas. Master

stations can usually initiate calls to other master stations or to other slave stations. Provisions can also be made for general announcements to all stations. Slave stations or remote speakers generally cannot initiate calls to master stations or to other speakers; however, most have talk-back features whereby two-way conversations can be carried on after a master station has initiated a call.

Intercommunication between classrooms and administration is standard practice in secondary schools and is used in some college planning. Occasionally for privacy a telephone handset is provided for the intercom speaker in university installations with a two-way switch linking the teacher to either the intercom desk or other facilities such as a dictation office or a computer operator.

RADIO

Radio systems are usually used for paging and maintaining contact with fixed stations and mobile units. The paging system consist of a transmitting station, either fixed or mobile where the portable receiver is carried by persons being paged. The portable units can have talk-back features or can be receiver sets only, requiring the person being paged to acknowledge the call by use of a telephone. A system used for communication with mobile units such as security vehicles requires that transmitters and receivers be located in fixed stations as well as mobile units. Calls can be initiated by either party and a response made instantly. The range of the units has a practical limit of approximately 35 miles.

ADVANTAGES

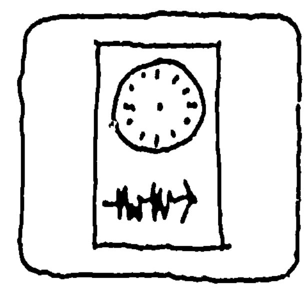
The advantage of radio systems is instant communication with remote points. When provided with reserve power, such as batteries, the systems are operational even during periods of complete power failure. Flexibility of the systems is limited only by the existing needs and cost considerations. Systems are capable of being designed and built for the specific functions desired.

DISADVANTAGES

The main disadvantages are that radio and intercommunications systems are not private. Persons near speakers of wired systems can listen to conversations and are aware of persons being paged. Signals for wireless systems can be monitored by any person having a receiver tuned to the same frequency.

In a case of wireless communication, permits must be obtained from the Federal Communications Commission for private channels and the use of Citizens Bands must be limited.

CLOCK AND SIGNAL



A master clock system with program signal circuits is essential for regulation of school activities and is desirable for control of utility functions as well. An accurate master clock drives, monitors and automatically

regulates all auxiliary clocks connected to it and also drives a programmer which may serve several separate circuits of signals. These signal programmers may operate automatically over a 24 hour period and may be manually operated or skipped at any desired time. Master clocks are usually equipped with spring wound carry-over movements and thus preserve the operation and setting of a clock and signal system for power failure up to twelve hours duration.

The master clock and programmer may also control heating and cooling, lights, fans and other associated devices in individual classrooms or entire buildings as desired. This often results in better diversity for utility systems and savings in operational cost.

SIGNALS

Signal devices for program systems consist of buzzers, bells and horns. Buzzers are ordinarily used for low noise level locations such as offices and classrooms; small bells are used in corridors and large work areas and large bells are used in gymnasiums and outside areas. Horns are generally used for fire and emergency signals.

ALARMS

The intercom system can be utilized as a vandal alarm by using the classroom speakers and a sensing device for unusual sounds and by triggering a relay which turns on lights, emits sounds through the speaker and alerts the campus or municipal police. This option is available in complete units comprising the master clock, programmers and sound console.

FIRE ALARMS

Fire alarm signals and emergency signals are also transmitted through the master signal system using program circuits reserved for that purpose and initiated by fire alarm devices.

WIRE CONNECTED CLOCKS

The oldest and most common clock and program system in use is the central system wire connected to signal devices. In this system all clock locations in all buildings are connected to and controlled by the master clock and programmer. All signal devices are wire connected also. Location of the master clock and programmer is usually in the administrative offices.

The advantages of a wire connected system are synchronization of all clocks and signals at all times, central control and operation by authorized personnel only and concentration of major maintenance at one point. The major disadvantages are:

1. The long wire runs to isolated buildings.
2. The possibility of accidental destruction through weather or cutting of underground wiring.
3. The necessity of rerouting overhead lines or underground cable when unforeseen construction occurs.
4. The number of clocks and signals controlled by this system being limited by distance unless additional power supply panels are located at remote locations.

A very large campus or a divided campus may require several separate master clock and programmer systems. Sometimes groups of buildings constituting a single division of a school are remotely located

on or off of the main campus and must be linked by a master clock system within the group. The main advantage of individual master clock systems is the elimination of wiring connections of dissimilar systems installed under separate contracts and a lack of coordination with the rest of the campus.

ELECTRONIC IMPULSE CLOCKS

An improved type of system is the electronic impulse system which uses a master clock and programmer as in the system described above and in which signals are impressed upon the electrical distribution system by a transmitter. The transmitter usually operates with four channels ranging from 13,000 to 25,000 cps (cycles per second) and each channel is capable of six circuits for programming. One of the four channels is usually reserved for clock monitoring and regulation and another is reserved for emergency or fire alarms. Reception of the frequency impulse signals occurs at clock bells and other devices attached to the 120 volt power lines in a normal manner. Receivers on the devices receive the coded impulses and respond to the correct frequency impulse.

The main advantages of electronic impulse systems are that central control of the system is preserved and synchronization of all clocks and signals is assured. Normal connecting circuits between clocks and/or signals in master clocks is eliminated and the chance of interruption is reduced. Expansion of the systems with future buildings occurs with the installation of the electrical system.

The disadvantage of the electronic impulse system is that the impression of the electronic impulse upon the power distribution must be as close as possible to the secondary side of the power distri-

FIGURE 20· **MASTER CLOCK - WIRE CONNECTED SYSTEM**

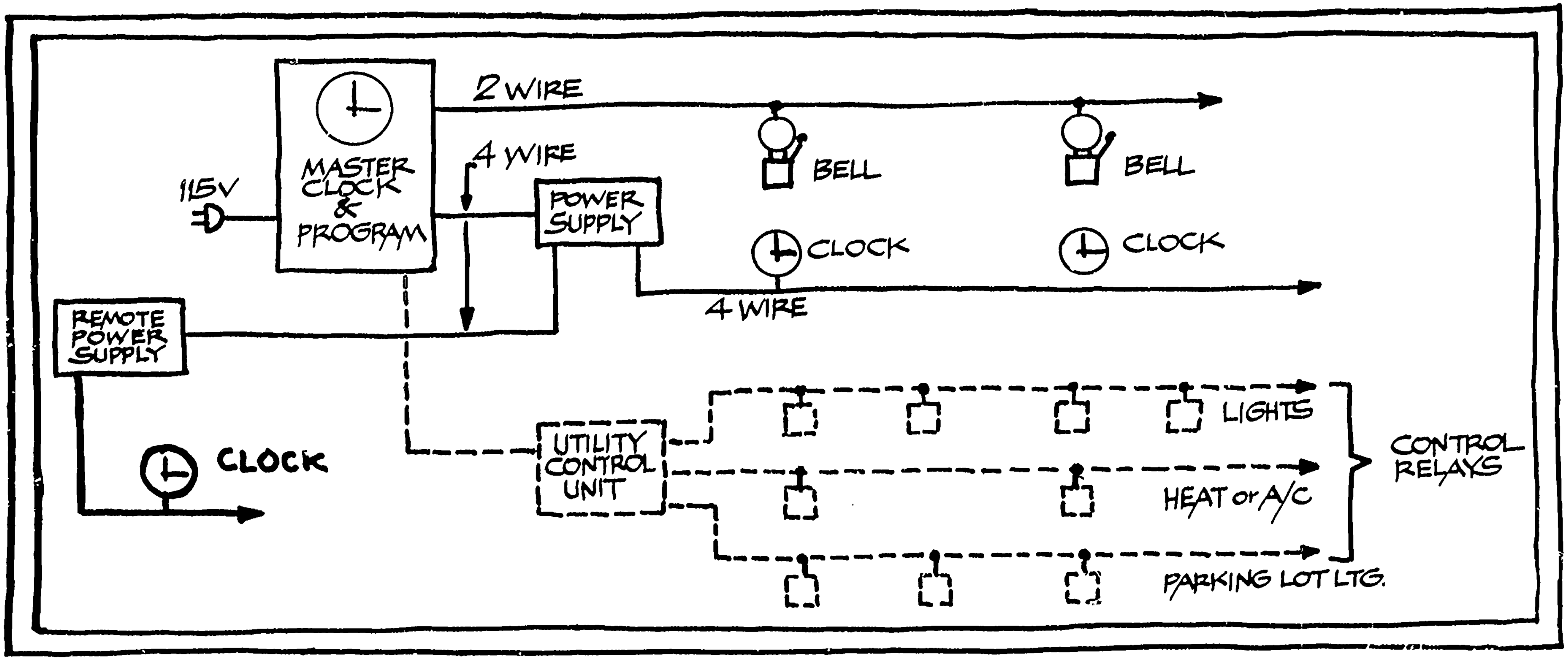
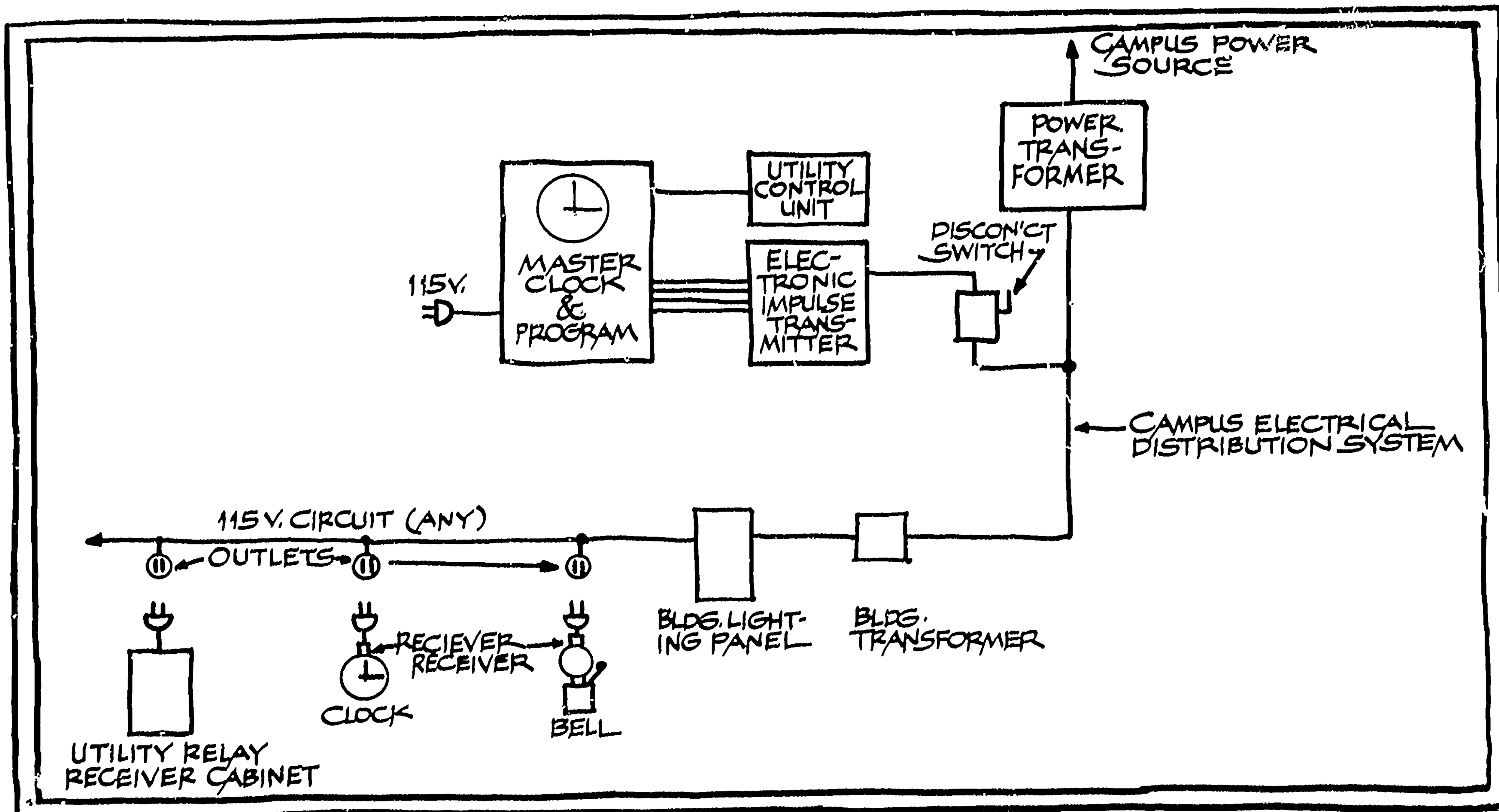


FIGURE 21 MASTER CLOCK – ELECTRONIC IMPULSE SYSTEM



bution transformer. On a large campus this may be a long distance from the master clock and programmer mecessitating several circuits of connecting wiring. Also, if a campus because of separated facilities should have separate electrical distribution systems or primary systems of different voltages, the electronic impulse system cannot be used for the complete school. Ordinarily the frequency impulses present no problem i electronic equipment but it should be remembered that in many college experiements are conducted in physics and other laboratories using high frequency oscillation electronic circuits. To prevent false operation of these or feed-back to the distribution that might trigger the signal system, isolation transformers must be supplied to the laboratory equipment.

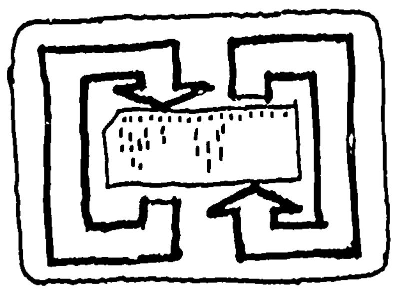
DISTRIBUTION

Distribution of interconnecting wiring where required by the clock and signal system can be in utility tunnels if they exist, by direct burial cable from building to building or by aerial lines following electrical distribution facilities. Distribution of electronic impulse systems is achieved by utilizing the electrical distribution system and requires no special wiring.

The selection of the system to use will depend greatly on the physical size of the campus, continuity of the campus, grouping of buildings or schools and density of buildings. A wire connected system would ordinarily be most economical for a campus with dense building concentration having utility tunnels serving each building. On the other hand a campus with widely spaced buildings and anticipating additions each year should seriously consider the electronic impulse system. The preceding Figures illustrate the two clock systems discussed.

The nature of the existing or planned electrical distribution system must be evaluated in considering the electronic impulse system. Also, availability and quality of maintenance personnel at the campus may influence the decision as wired systems are relatively uncomplicated. Electronic impulse components must be served by persons with special training in maintenance and with equipment for testing these devices.

DATA STORAGE, RETRIEVAL AND TRANSMISSION



Recent developments have produced many new methods of data storage, retrieval and transmission. Computers can be used to analyze attendance, predict peak demands on classrooms, cafeterias and assembly rooms, and store a multitude of information which can be made available electronically to different departments either at a central point or at each department. Data storage and retrieval systems can store either electronically or on microfilm such information as library references, attendance records and lectures and papers presented in classrooms or meetings. These can be reproduced on scanning screens, on printed sheets and in audio form depending upon frequency of use, permanency of storage and availability of information desired. Teletype machines can relay information from any one point to another or from all points having teletype machines of the same system. Teleautograph machines make possible the transmission of handwritten messages to different departments or buildings simultaneously with the writing of the messages.

DATA STORAGE

Data storage, retrieval and transmission systems make possible the storage of great amounts of information in the minimum space. The retrieval system is rapid and accurate and minimizes loss of information. Information is always available for rapid use.

Data storage and retrieval systems can also provide information directly to student dormitory rooms by direct dialing to the storage centers, the university library and data storage area. Such a system permits a student to sit in his room and dial a request for information, receiving it instantly on his viewing screen or by print-out or by audio transmission. The development of new systems in recent years forecast many additional improvements in years to come and all planners should be aware of these systems as they become available and proven.

CLOSED CIRCUIT TELEVISION

Closed circuit television systems are used for such functions as classroom instruction, observation, monitoring and security. The systems are capable of permitting continuous operation and can be provided with attachments which when connected to television circuits will produce printed material and photographs. These systems are excellent for the observation of experiments by a large group.

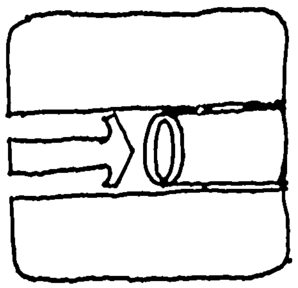
The main advantage of these systems is that continuous monitoring at many points may be made from one location and important lectures, speeches and lessons may be presented to a large number of students without the necessity of a large assembly hall. The main disadvantage is their cost and the

requirement for maintenance specialists. This may be offset by the savings in other physical facilities.

DISTRIBUTION

Distribution of communication circuits are made by wire and conduit within buildings and between buildings. This may be by aerial systems or conduit and circuits routed in utility tunnels. Data retrieval systems may require shielded circuits.

PNEUMATIC TUBE

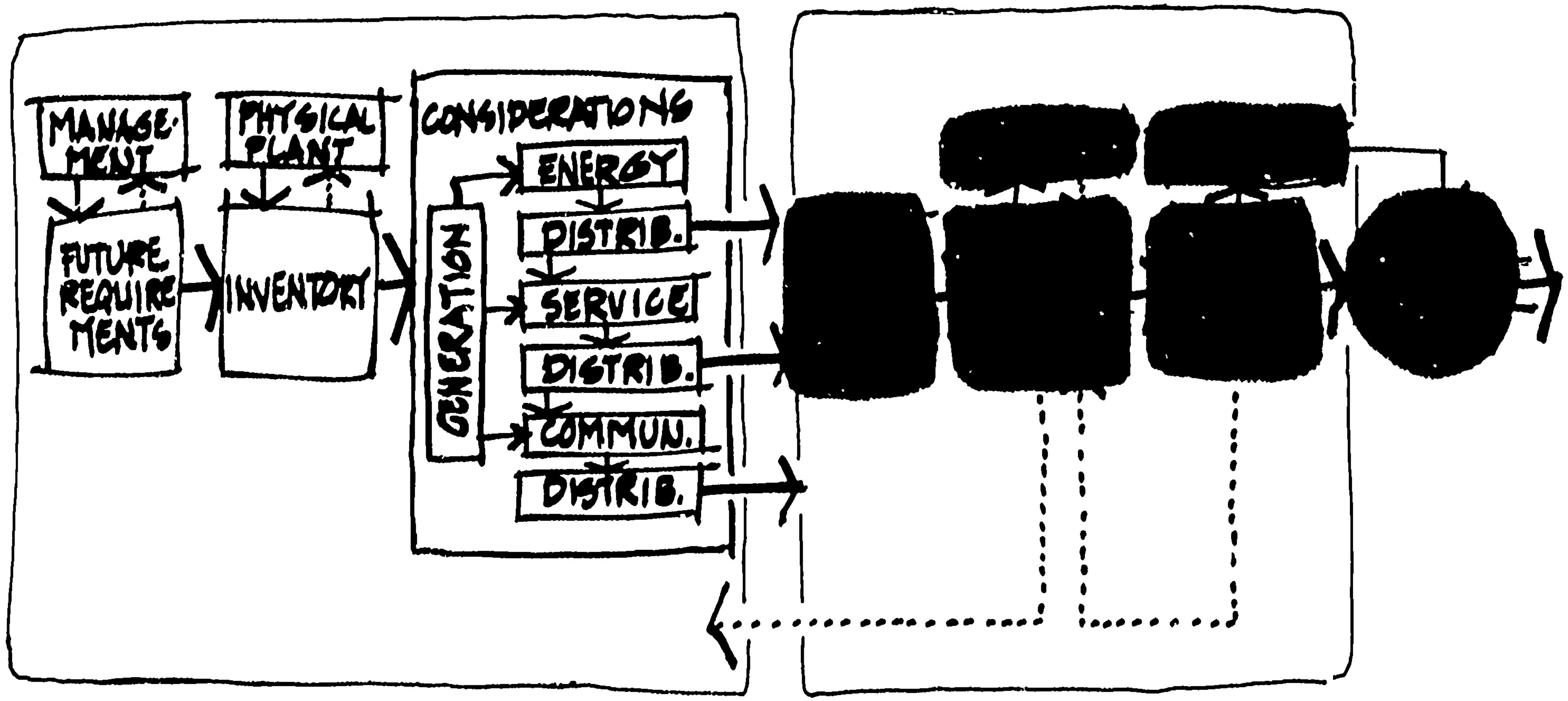


The primary use of pneumatic tubes is conveyance of written messages and receipts. Pneumatic tubes have fixed stations at predetermined locations. Carrier tubes 3 to 4 inches in diameter connect all fixed stations. Two tubes per station are usually required, one tube a sending tube, the other a receiving tube. Pilot lights at the receiving ends indicate the arrival of carrier cylinders.

The main advantage of pneumatic tubes is conveyance of private messages between stations. However, the disadvantage is that the size of the documents capable of transmittal is limited. The delivery time is rapid but response is indefinite depending upon prompt attention at the

receiving station. Permissible transmission distance is also limited and tube routing must be carefully coordinated with building architecture and structural and mechanical work. Generally such systems are limited to utilization within the individual building and are for special application.

PLAN DEVELOPMENT



ANALYSES

The previous sections have presented guidelines on the considerations and studies that must be made relative to each of the individual utilities. The development of a final plan now calls for the following steps:

(1) Thorough analysis of data for all aspects of the utility study;

(2) Definition of utility requirements for the planning periods;

(3) Cost Analyses;

(4) Identification of alternative approaches, considering requirements and resources.

UTILITIES PLAN

The results of the analytical studies should permit the development of specific plans for each of the individual utilities. The plans would provide direction for new construction, general maintenance, minor and major modifications and replacement. A time schedule for implementation of the utility plans provides the final recognition of priorities within the system.

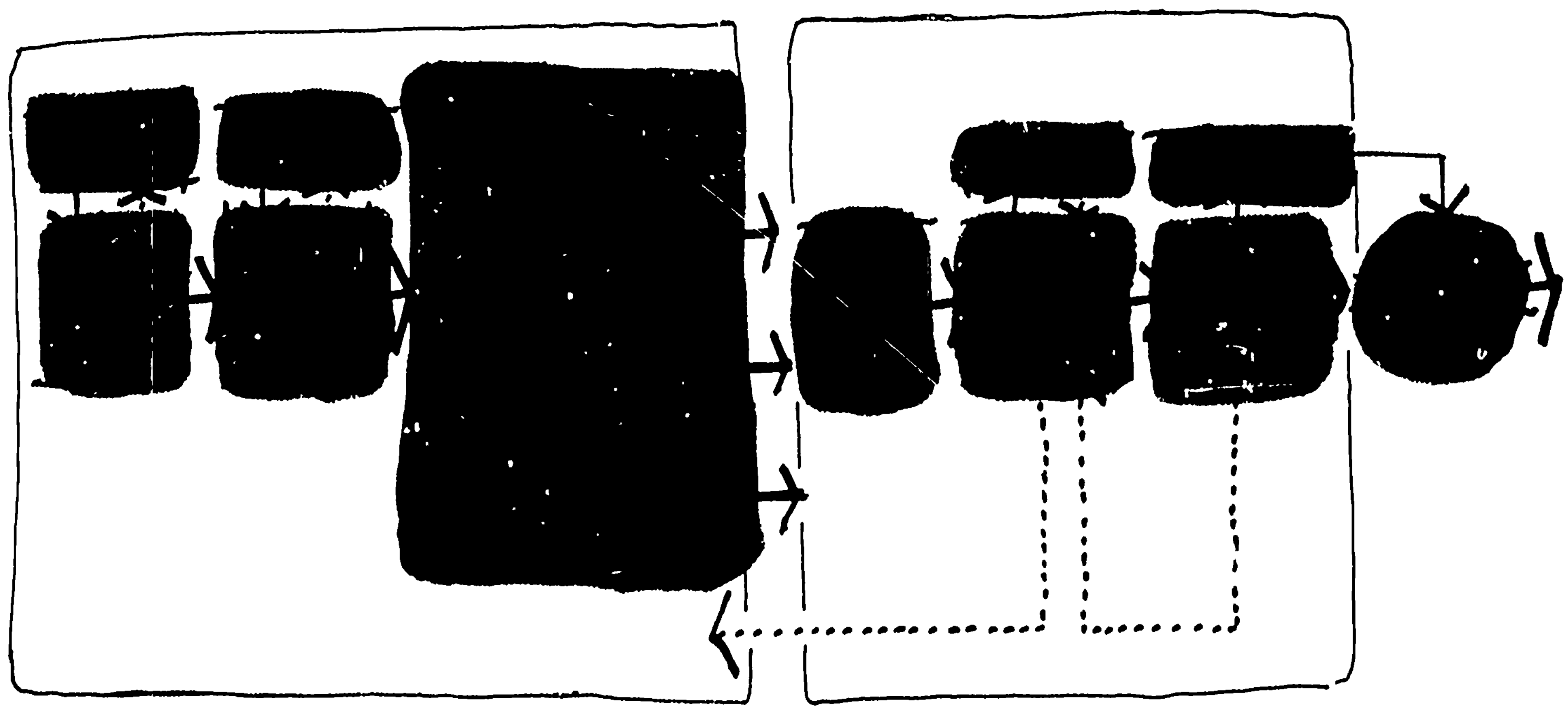
TOTAL CAMPUS PLAN

The final step is to incorporate the results of the utility planning process into the total campus plan. It is of particular importance here to relate to the overall construction of physical facilities. This will help to assure a desired work schedule which provides a logical construction sequence such as construction of a utility tunnel across a parking lot prior to its being surfaced rather than after it has been surfaced.

ANNUAL UPDATE AND REVIEW

The process of university development is highly dynamic and change in objectives and priorities with time is to be expected. The utilities plan must be reviewed annually and updated as necessary it if is to play a meaningful role throughout the time span of the planning period.

SUMMARY



To summarize, the utilities should have great influence on physical plant planning for a campus. They must be considered concurrently with other factors during the management decisions on campus location, land utilization, and budgetary requirements. Energy utilities have the highest initial and operating costs and consequently require the greatest coordination. However, all utilities systems are expensive and must be carefully planned.

Strategic locations of central plant facilities and proper planning of initial and subsequent campus building locations can result in the lowest utilities systems cost initially and continued low cost with expansion through good planning. Poor initial planning may result in expansion bottlenecks and high utilities costs due to the necessity of extensively revising existing systems to meet the new requirements instead of following an organized pre-planned expansion program of scheduled additions to utilities systems.

Campuses located in large municipalities will generally find relatively low cost water and power supplies available as well as sewage and surface drainage disposal through existing municipal systems. Campuses located in remote areas may be faced with providing their own water supply and sewage disposal plants and may find the cost of electric power from available sources sufficiently high as to require generation of power within the campus utilities system.

The utilities systems planning of any new campus or enlargement of any existing campus must take into consideration future growth and at least provide space for installation of future equipment. Where practical, sufficiently large distribution mains, tunnels, and central plant buildings should be provided to accommodate the required capacity additions in the future. This may result in higher initial costs but considerably lower ultimate costs for the campus utilities systems.

These advantages must be weighed against budgetary limitations and be commensurate with the time of future expansions and method of financing.

It is of prime importance that the planning of campus utilities be coordinated with the overall planning. A coordinated effort will produce the lowest costs and best coordinated and planned systems. The best systems will provide the least interference with the other operations of the campus and contribute to the overall appearance and image as a college campus.

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ADDITIONAL VOLUMES

The following outlines describe Volumes I thru IV which precede and compliment this volume:

VOLUME I - PLANNING SYSTEM

I. Introduction
- A. Background
- B. Planning Requirements
- C. Project Scope
- D. Project Organization
- E. Project Presentation
- F. Time Span
- G. Community Considerations

II. Management and Program Planning
- A. University Objectives
- B. Program Plans and Requirements
- C. Planning Report . Academic Departments
- D. College Summary
- E. Planning Report . Research and Public Service and/or Extension
- F. Planning Report . Support Organizations
- G. University Summary

III. Physical Plant Planning
- A. Facilities Planning
- B. Traffic Planning
- C. Utilities Planning
- D. Land Use Planning
- E. Physical Plant Planning Process

IV. Financial Planning
- A. Multi-Year Budgets
- B. Financial Evaluation
- C. Cost Estimation
- D. Income Estimation
- E. Planning-Programming-Budgeting

V. Total University Plan

VI. Continuous Planning System
    A. Dynamic Planning
    B. Organization

VII. Summary

VOLUME II - MANAGEMENT AND FINANCIAL PLANNING

I. Introduction
    A. Planning System
    B. Management and Program Planning
    C. Financial Planning
    D. Organization for Planning
II. Institutional Objectives
    A. Fact-Finding Study
    B. Preliminary Objectives
    C. Review and Modifications
III. Organizational Unit Plans
    A. Program Units
    B. Support Units
IV. Planning Report - Program Implementation Units
    A. Format
    B. Historical Section
    C. Projections
    D. Program Requirements
V. Planning Report - Program Support Units
VI. Management and Program Planning Summary
VII. Organization for Planning
    A. Basic Considerations
    B. Development of Planning Organization
    C. Staffing of Planning Organization
VIII. Cost Model
IX. Income Model
X. Planning - Programming - Budgeting
    A. Definition
    B. Program Concept
    C. Program Requirements
    D. Resource Allocation

VOLUME III - PHYSICAL PLANT PLANNING ● LAND USE AND TRAFFIC

I. Introduction

- A. Land Use
- B. Traffic

LAND USE PLANNING SECTION

II. Introduction

III. Basic Determinants - Information Inputs
- A. Management
- B. Financial
- C. Physical

IV. Basic Determinants - Investigation, Analysis and Program Development
- A. Problem Identification
- B. Planning Assumptions

V. Design Factors - Evaluation, Testing and Selection
- A. Tangible Design Factors
- B. Intangible Design Factors

VI. Land Use Plan - Synthesis
- A. Land Use Scales
- B. Land Use Alternatives
- C. Land Use Plan

VII. Detail Design and Implementation

VIII. Continuing Planning

TRAFFIC PLANNING SECTION

IX. Introduction
- A. Conditions
- B. Basic Elements

X. Access
- A. Street System Inventory
- B. Traffic Characteristics
- C. Traffic Assignment

XI. Internal Circulation
- A. Street Inventory
- B. Characteristics of Pedestrian Movement

XII. Parking
- A. Supply Inventory
- B. Characteristics Study
- C. Future Types

XIII. Special Events
- A Attendance
- B. Routing
- C. Control Coordination

XIV. Traffic Plan
- A. Analysis of Results
- B. Construction of Facilities
- C. Control Plan

VOLUME IV - PHYSICAL PLANT PLANNING • FACILITIES STUDIES

I. Introduction
   A. Problem
   B. Required Studies
   C. Presentation
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